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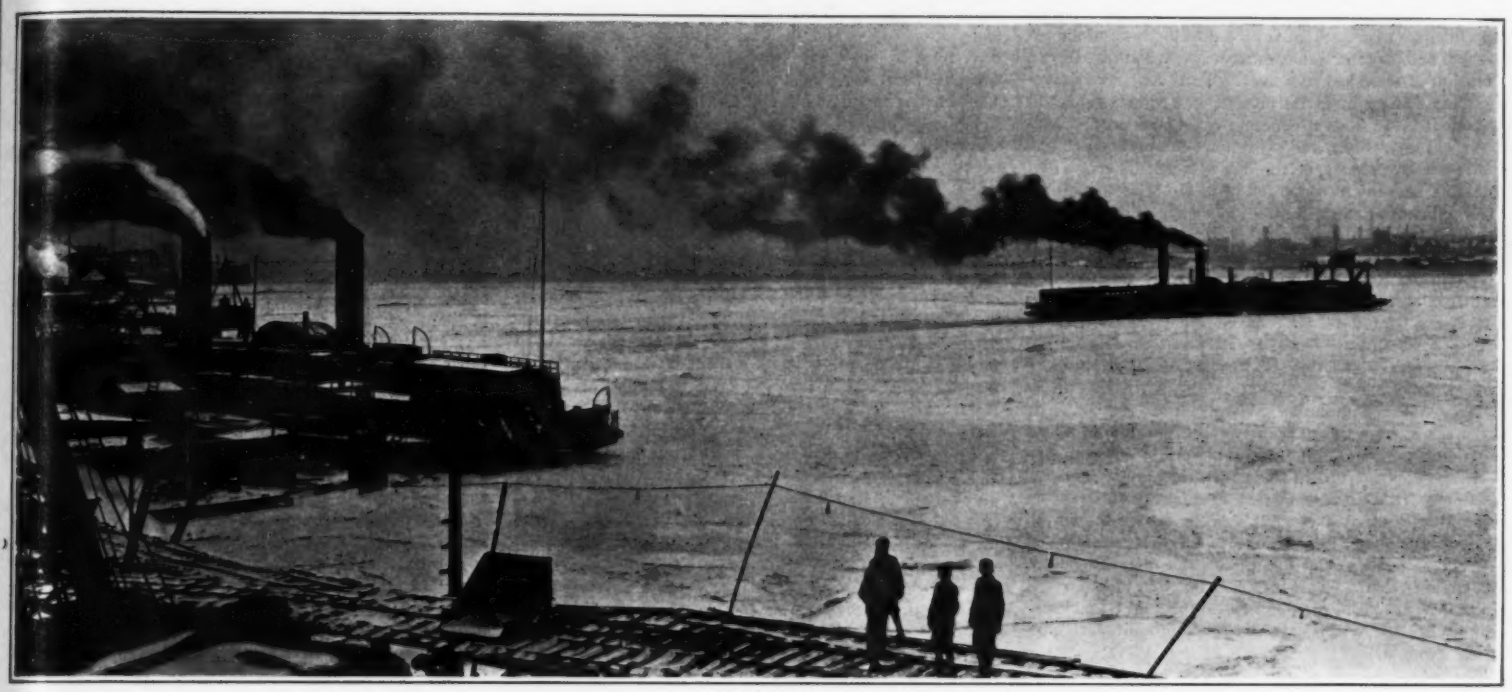


The old way of transferring trains across the Detroit River on boats.

Trains now pass through the tunnel under the Detroit River in less time than it formerly required to put them on the transfer boats.

AN IMPORTANT TERMINAL IMPROVEMENT.—[See page 308.]

Modern Psychology*

The Present Study of Character and Temperament

The successive claimants to the domain of "character and temperament" may be said to have momentarily triumphed and passed away, without accredited issue. The new sovereignty represents a very different allegiance. It shares in the common heritage of modern science. The notable extension of knowledge through experiment is ever paralleled by a development of logical method and critical interpretation, as well as by an extension of technical resources. To this general movement psychology owes its present status, and shares in its benefits. It finds a concrete expression in the psychological laboratory, and a yet more comprehensive one in the transformation of the entire range of accredited problems, and the introduction of new realms of inquiry. The technical advance in the knowledge and control of physical, biological and psychological forces characterizes the modern world of science. These divisions of intellectual enterprise, though differently directed, are mutually corroborative. They progress by the application of a common logic. *Standards of evidence, extension of data*, and *the basis of interpretation* develop together. Jointly they determine the spirit of modern science, from which psychology along with the rest of sciences, receives its directive bent and the temper of its pursuit. A co-ordinate factor is the dominance of an expanding practical philosophy—a worldly wisdom born of a larger experience in social, political and economic relations. It is expressed in the standards of intercourse and living, and more particularly in the cosmopolitan outlook, reflecting the insight into the determination of events and careers as of the qualities of men shaped by, and shaping them. This influence extends to literature, philosophy and the arts of life; it provides the background against which the technical pursuits are projected, from which they emerge.

The establishment of the principles and the body of knowledge determining the present study of character and temperament is the convergent product of a complex development; it forms an integral part of the general advance for which the nineteenth century—the culmination setting in with marked acceleration in the second half thereof—is notable. Our purpose will be served by considering broadly the contributory branches of investigation to which psychology is particularly indebted. Among these the establishment of the relation between body and mind is clearly central. Equally fundamental is the interpretation of the vital processes and provisions through a unifying and illuminating principle. This was supplied by the master-key of evolution, and at once rationalized and vitalized the conception of origins and transformations of natural processes and products—including the manifestations and endowments of the mental nature. Interpretation became possible in a convincing language—quieting the babel of tongues. Both of these guiding principles—the latter particularly—were revolutionary in their influence, not primarily by the new extension of knowledge and interest (which was in the main a consequence of the new insight), but by the introduction of a new interpretation. Familiar facts were given a distinctive and a richer meaning. The perspective of significance was notably altered. This momentous reconstruction of the biological realm indicates in a few words the decisive factors that made modern psychology possible. The brevity of the record should not diminish the appreciation of its vital importance.

The development of the knowledge of nervous function has a venerable history. The recognition of sensation and movement in relation to the nerves occurs sporadically and irregularly in Greek, Roman and medieval medicine, at times with a shrewd interpretation of symptoms. It seems never to have been made a leading principle, but was held in detachment from the general notions in terms of which conclusions were stated. Hippocrates, Galen and their followers occasionally record observations in which a limited loss of movement (paralysis) and loss of sensation (anesthesia) were referred to interference with the action of certain nerve-trunks. Such observations remained casual and incidental. The usual explanation of the bodily accompaniments of mental action were given in terms of the flow of the "vital" spirits, with the veins (supposed to contain air), as the true channels of the flow that determined sensation; while the ventricles (literally breathing spaces—actually the channels for the cerebro-spinal fluid), were assigned the central part in the vital service. Vesalius, founder of modern anatomy, knew by experiment apparently as well as through inference from observation, that section of the nerves abolished muscular control and that the loss of the medulla deprived an animal of sensation and movement. He contested the notion that faculties like memory could reside in such spaces as the ventricles of the brain. But such views were heretical to the scriptural authority of Galen and Hippocrates, and were timidly expressed and pursued. As a type of conception matured under philosophical pursuits critically maintained and in relation to the science of the day, may be cited the view of Descartes. He looked upon the nervous system as a mechanical automaton—somewhat after the manner of an elaborate and fantastic "playing" fountain, whose ingenious streams turned windmills and started miniature water-spouts. The nerves were conceived as tubes for the flow of "animal spirit," or of some similar agency, with the pineal gland in the center of the system as a controlling valve directing the flow—the flow according to the course resulting in one kind or another of mental process. Even Willis, despite his insight into the structure and function of the brain and the complex provisions for its circulatory system, could speak of it as an instrument which the "soul inhabits and adorns with its presence." He conceived the blood as a vital flame, through which products of combustion arose and in turn gave rise to mental processes. Each variety of physical change which the physiologists and chemists discovered in the laboratory of the body—such as distillation and absorption, or fermentation and evaporation, along with the older conceptions of animal spirits (the latter term used confusedly at once in a psychological and a chemical sense; hence "spirits" of ammonia, turpentine, etc.), were in turn called upon to account for the transformations responsible for the elementary mental processes.

There is nothing notably distinctive in the successive formulations of "nervous" function from the days of Harvey, who gave the directive impetus to physiological conceptions, to those of Haller, who first applied them with marked success to develop the conception of nervous responsiveness (irritability) through specific adaptation of the organism to the stimulus. Haller was not free from the speculative vagaries of his predecessors; yet he thought of the problem of the physiological basis of mental processes consistently and clearly. His contributions so decidedly advanced the conception of nervous function that it was relatively easy to make the transition to the true interpretation given first by a group of physiologists in the early nineteenth century (Marshall Hall, Charles Bell, Majendi), and culminating in the actual measurement of the rate of nervous impulse by Helmholtz in 1850. The position of Haller is notable not only for the general correctness of his conclusions and the experimental evidence upon which they were based, but equally because he separated so clearly what was conjectural from what was established. In a number of cases the task of his successors was merely to follow his lead and transform conjecture into proof.[1]

This account of one strand in the network of data indispensable to the establishment of a psychological point of view is presumably typical of parallel movements. It indicates how recent are the steps of direct bearing upon present-day problems, and in so far justifies the slight consideration (in the present connection), of the remoter and more fragmentary historical antecedents. It will also make it easy to understand how readily in the absence of an accredited and established view of the bodily correlates of mental action, the ambitious innovations as well as the traditional survivals of beliefs could gain a foothold. This is true in part of even so late a propagandum as that of Lavater—which in large measure was operative before the day of the most decisive discoveries—and to the careers of Gall and Spurzheim, whose contributions in part came after them. The spirit of nineteenth-century science was not then sufficiently disseminated to make obvious the irrelevancy of such pretensions as phrenology, nor indeed to offer a satisfactory consideration of the problems which that system professed to solve.

In the collateral ancestry of "character and temperament" the anthropological attitude occupies an important place—in a new sense making mankind the proper study of man. It forms part of the broadening outlook upon the constitution of nature in general and human nature in particular, that characterizes modern thinking. It doubtless has a relation to the closer study of the political struggles of nations and to economic expansion, though the relation is not intimate. It aimed at a philosophical interpretation of the structure and motive sources of human society and institutions. The anthropological interest extended to the characteristics of the social groups, particularly of races and peoples in different stages of development and under the sway of distinctive cultures. The enlargement of outlook resulted from the spirit of exploration and inquiry, which brought knowledge of peoples and habitations and other systems of culture, and in another direction extended the reconstruction of the past of man. A similar enterprise resurveyed the story of the intellectual past and traced the slow control of the forces of nature through invention, and the equally laborious attainment of a social control through the organizations of men. The larger intercourse with varieties of mankind together with the broader interpretation of the forces responsible for the development resulting from the same spirit of exploration and inquiry that led to the technical scientific advances, brought with it a more thorough knowledge of the diversity of men and civilizations, and traced in the latter the issues of the interplay of desires, capacities and beliefs, by which to interpret our own and (with allowance) foreign natures. Culture acquired a more real and a richer meaning as a psychological product, and therewith conferred a new insight and a new obligation upon the psychologist. The diversity of men was thus related to their divergent solutions of the problem of shaping their lives to satisfy needs, impulses and desires; and the environment, so largely a psychological one, acquired its full significance. The study of human nature embraced more than that of one time and region and status. The more recent emphasis of the sociological aspects of life is in the larger view an issue of the anthropological interpretation, but is yet more characteristic of the attitude now dominant, and properly called modern. The psychology of the social relations was thereby made an integral part of the study of human character.

Two further aspects of the qualities of which character and temperament form the realistic composite, are the genetic aspect, and the abnormal—the pathological aspect. The growth of traits is an essential part of their nature. It implies a reference to the setting in which they operate, to which they are adapted, by which they have been shaped. It implies equally the reference to the vital course, the maturing unfoldment of native endowment, which makes the biological aspect of human nature the most comprehensive and the most elemental. Within this compass the determination of hereditary forces and their mode of operation assumes a special importance. The traits forming the composite of Character and Temperament are part of the biological inheritance, are the issues of forces whose funamental significance is the biological one. Accordingly (despite or in addition to our more detailed interests in other aspects), they must reflect and conserve the allegiance to this underlying relation. More specifically, the genetic aspect differentiates the outlines of the stages of growth; in its terms are described the orbit of the psychological cycle. It yields the psychology of infancy, of adolescence, of maturity, of senescence, and presents the course of the included qualities in mutual illumination. The genetic argument emphasizes a progressive environment and a progressive purpose; it enlarges the scope of adaptation, and it interprets the impetus and goal in varying interests and endeavors. It was never absent from the accredited psychology of human nature, but in the modern view it assumes an explicitness and a directive position that constitutes it a notable factor among the available resources. It has powerfully affected our entire view of

* By Prof. Joseph Jastrow, of the University of Wisconsin, in *The Popular Science Monthly*.

[1] An admirable statement of the development of knowledge of the nervous system is found in Sir Michael Foster's "Lectures on the History of Physiology" (1901), Chapter X. G. Stanley Hall's "History of Reflex Action" (*American Journal of Physiology*, January, 1896), should also be consulted. Andrew D. White's "History of the Warfare of Science and Theology" (1896) provides an illuminating commentary upon the movement of thought through which the present subject reached its modern stage. Of the histories of psychology that of Dessoir (1912) contains the most distinctive appreciation of the "character and temperament" movement. Of the more recent studies the most noteworthy are: A. Levy, "Psychologie du Caractère" (1896); Malapert, "Temperament et Caractère" (1902), "Les elements du Caractère" (1906); Alfred Fouillé, "Temperament et Caractère, etc."; Paulhan, "Les Caractères" (1894); Th. Ribery, "Essai de Classification Naturel des Caractères" (1902); L. Klages, "Prinzipien der Characterologie" (1911); Sternberg, "Characterologie als Wissenschaft" (1907); C. J. Whitby, "The Logic of Human Character." These works are by no means of comparable value, scope or treatment; nor does any one of them interpret accurately the message of modern psychology upon the subject. The literature bearing upon the training of character is large, but not pertinent to the present survey. Of books of other purpose with important bearing upon the subject may be mentioned MacDougall, "Social Psychology" (1908, and Wallas, "The Great Society" 1914). A peculiarly notable volume is A. F. Shand, "The Foundations of Character" (1914). No reference is made in the retrospective view or in the recent literature to the several modern attempts to develop "readings of character" from signs and systems of appearance or expression. The best-known of these is palmistry and graphology. That handwriting has a modest place as an expression of the neuro-muscular function is an admission that in no sense qualifies it to serve as an index to "Character." That a few students of handwriting have appreciated the physiological and psychological aspects of their findings is to be recorded.

human qualities, has extended our data and enriched their interpretation.

A parallel statement may be made of the argument from the decay, the faulty development, the inherent liability to perversion, of natural qualities, which are responsible for the pathological, the abnormal, the divergent aspects thereof. Useful adaptation, due proportion, tempered blending, related emphasis of traits stand as the normal issue; the divergence or failure thereof becomes the abnormal. The abnormal in excess or defect takes its place as an instrument of analysis and an enlargement of data. It is a distinctively modern resource, particularly in refinement of application.

It is in such general terms that the line of descent of the present psychological interpretation of human endowment proceeds. The more specific history of the attempts to formulate the resultant positions is brief. The classic chapter (Book VII, Chapter V), "Of Etholegy, or the Science of the Formation of Character," in John Stuart Mill's "System of Logic" (1843), though a programme rather than a contribution, still has significance. The project was undertaken by Alexander Bain in a volume bearing the title "On the Study of Character" (1861). Though Bain wrote at a time when psychology had made rapid advances and the vagaries of phrenology had been retired to their proper place, he devoted a considerable portion of his book to a refutation of the phrenological position. He thus conferred an undeserved dignity upon these findings and gave his constructive views an unfortunate setting. The subject was independently pursued by a group of writers (mainly in France and Italy), whose contributions in part belong to the living literature of the subject.[2]

It remains to touch upon the collateral streams of interest which in modern times maintained the study in one or another aspect, thus bridging the gap between the old and new learning. Among these is the attempt, never wholly absent in practical ages to guide training, to indicate on the basis of an analysis of character the promise of youth, and the direction of vocation—all in the spirit of a worldly wisdom. As an example of the earlier period, the work of the Spaniard, Huarte (1530–1592) "The Trial of Wits," may be cited, since it seems to have attained a large circulation, was translated into several languages (the English edition appearing in 1698), and the German so late as 1752 by the great Lessing (1729-1781). There were other writings of similar import both before and after Huarte. It is, however, difficult to estimate their influence in the current of thought destined to be redirected in a more scientific analytic interest. There is no hesitation, however, in recognizing in the works of Kant (1724–1804), a dominant influence in the rehabilitation of the subject. This appears not alone in his recognition of the claims of the practical reason, but notably in his "Anthropology" (1798). Indeed Kant's use of this term corresponds more closely to a study of the individual differences of men—which the problems of character and temperament consider—than to the content of the science which now bears that name. Special attention should also be directed to his 'Observations on the Sense of the Beautiful and Sublime," in which is given in a modern vein a detailed analysis in the field of the emotions, with excursions into the comparative psychology of the sexes and of nations. It shows the shrewd analyst in an engaging light. Of the writers affected by the Kantian position, who realized that the study of character offered a great field for the applications at once of philosophy, of anthropology and of education, Julius Bahnsen is the most representative. His work on "Charakterologie" (1867) both in method and scope represents the attempt to reach general and practical conclusions in the spirit of the early nineteenth century. It does not incorporate the views of the bases or sources of character which were even then available and which were represented by a group of German physiologists, such as Johannes Müller (1801–1858), K. F. Burdach (1776–1847), (and in a different temper Lotze and K. G. Carus)—who as sympathetic with the life of the practitioner brought to their philosophical generalizations the spirit of exact knowledge.

The establishment of modern psychology is the culmination of any interests; in no aspect is this historical development more significant than in regard to the sources of the view of the qualities of men as applied in modern life. The attempt to short-circuit the route from theory to practice, from understanding to application, has always ended disastrously. The correctness of the foundations determines the strength of the edifice. The study of the nervous system and the recognition of the subjection of all human traits to an evolutionary process laid the foundations. The sociological expressions of human qualities were related to their biological significance. The competition of human qualities received a psychological interpretation. Narrow views were avoided by considering the varieties of human culture and expression. Institutions, though dominantly an environmental product, became significant as embodiments of psychological needs and their satisfaction. Vocations became directions of special endowments. National characteristics were similarly interpreted. Education was seen to be a transformation of original trends as well as a direct preparation for the situations of an artificial life. Human nature was at once the material upon which all desired ends had to build, while yet to be remodeled for such cherished purposes. A closer knowledge of the mode of working of the human endowment resulted from the experimental study of the underlying processes of the mind. Language, art, science, customs, social institutions, political relations, reflected the spirit of a collective mind, though often articulate through the original contributions of favored individuals. With this combined equipment the psychologist of to-day proceeds to the interpretation of the traits of men summarized in the study of character and temperament. The antecedents of this view form a notable chapter in the development of the human mind, in the story of the control of the psychic forces of which culture is a record.

[2] See previous note.

Balkan Frontiers

Complex Problems That Do Not Conform to Race Distinctions

THE problems of Balkan frontiers are bewildering in their number and complexity. Every State in southeastern Europe can claim plausibly, and perhaps with justice, that the existing boundaries rob it of citizens naturally assigned to it by race and racial sentiment. Every State can argue with reason that the last settlement leaves it at a disadvantage strategically and economically. Every State, in a word, looks beyond its borders to population and territory under alien government. Thus, Rumania must think of Rumanians in Transylvania and Bessarabia, Bulgaria of the Bulgarians in Macedonia, Serbia of Serbians in Bosnia, Greece of Greeks in Albania. The catalogue might be elaborated and complicated indefinitely.

The primary reason for this entanglement of races is the Turkish invasion of Europe. Just as when the Roman Empire fell and its territory was divided into independent realms, centuries elapsed before States were formed upon the principle of nationality, so in the Balkans, the collapse of the Ottoman power has been followed by a period of conflict and intrigue from which truly national powers are only now beginning to emerge. When a number of races have long been subjected to the government of some alien power, it is not to be expected that they can swiftly consolidate themselves into harmonious independent units.

The problem of the Balkans is further complicated by the configuration of the peninsula. The natural geographical divisions have little or nothing to do with the divisions of race. For example, the main range of the Balkan Mountains, which seem destined by nature for a racial frontier, runs east and west through the very heart of Bulgaria, dividing a population united in blood, language, and sentiment. The boundary between Austria and Rumania along the line of the Carpathians seems the most natural of frontiers. But, in fact, it leaves under the Austrian yoke a large population essentially Rumanian. It would be easy to multiply such examples.

The government of Bucharest, though it has to consider the problems of a Rumanian Irredenta, has at least frontiers which follow physical divisions. On the south the great stream of the Danube forms the Bulgarian boundary, until at Oltenitza the river barrier is replaced by an imaginary line running in a southeasterly direction to the Black Sea a few miles north of Varna. The Danube has been the frontier throughout the existence of the two States. The present imaginary line in the eastern portion of the frontier was drawn by the Treaty of Bucharest, which added to Rumania nearly 3,000 square miles of territory and a population of 2?6,000. As for racial claim to this eastern district, we may note that neither Bulgaria nor Rumania had a very clear title.

The line of the Danube is an important obstacle. Where the river enters Rumania it runs through a gorge shadowed by mountains more than 1,000 feet high. The stream is less than 150 yards wide and of great depth and speed. At the Rumanian end of the gorge are the famous "Iron Gates," a rapid so named from a number of submerged rocks. Once out of the mountains the river rapidly expands, and runs through flat and marshy country. It is, therefore, a formidable, but not an impregnable, barrier, as the Rumanian army showed in July, 1913, when a swift and easy crossing was made at Silistria.

The Austrian frontier of Rumania, the Carpathian and Transylvania mountains, forms a line which offers far more serious obstacles. There are several passes of little more than 1,000 feet, crossed by railways in the Transylvania range, but the Carpathians to northward are less accommodating, and it is commonly held that the frontier is strong against attack from either side if resolutely defended with adequate forces. The boundary between Russia and Rumania is the River Pruth and the northern mouth of the Danube. This must be called a convenient rather than a well-marked frontier. Moreover, it leaves to Russia the Rumanian population of Bessarabia. This is in accordance with the provisions of the Treaty of Berlin, which, in exchange, assigned to Rumania the Dobrudja, the strip of territory between the Black Sea and the northern bend of the Danube, a settlement unsatisfactory to Rumanian aspirations. In the Dobrudja, however, is situated Rumania's one sea port, Constanza. This is now a place of 26,000 people, with a considerable export trade in cereals and petroleum. Its harbor is not wholly satisfactory, and in the bitter northeast wind, for which the Black Sea is famous, the entrance is not without danger.

Nevertheless, much has been done to improve and increase the natural advantages of the port, which can now accommodate large vessels, and has a considerable mechanical equipment. At the present juncture it may be of interest to note that, in spite of its scanty seaboard, Rumania possesses the germ of a navy. Besides one antiquated little cruiser there are half a dozen gunboats, as many torpedo boats, and four monitors. But most of these craft are intended for work on the Danube. It may be added that there are elaborate fortifications around Bucharest and some extensive works in the northwest near the Transylvanian frontier.

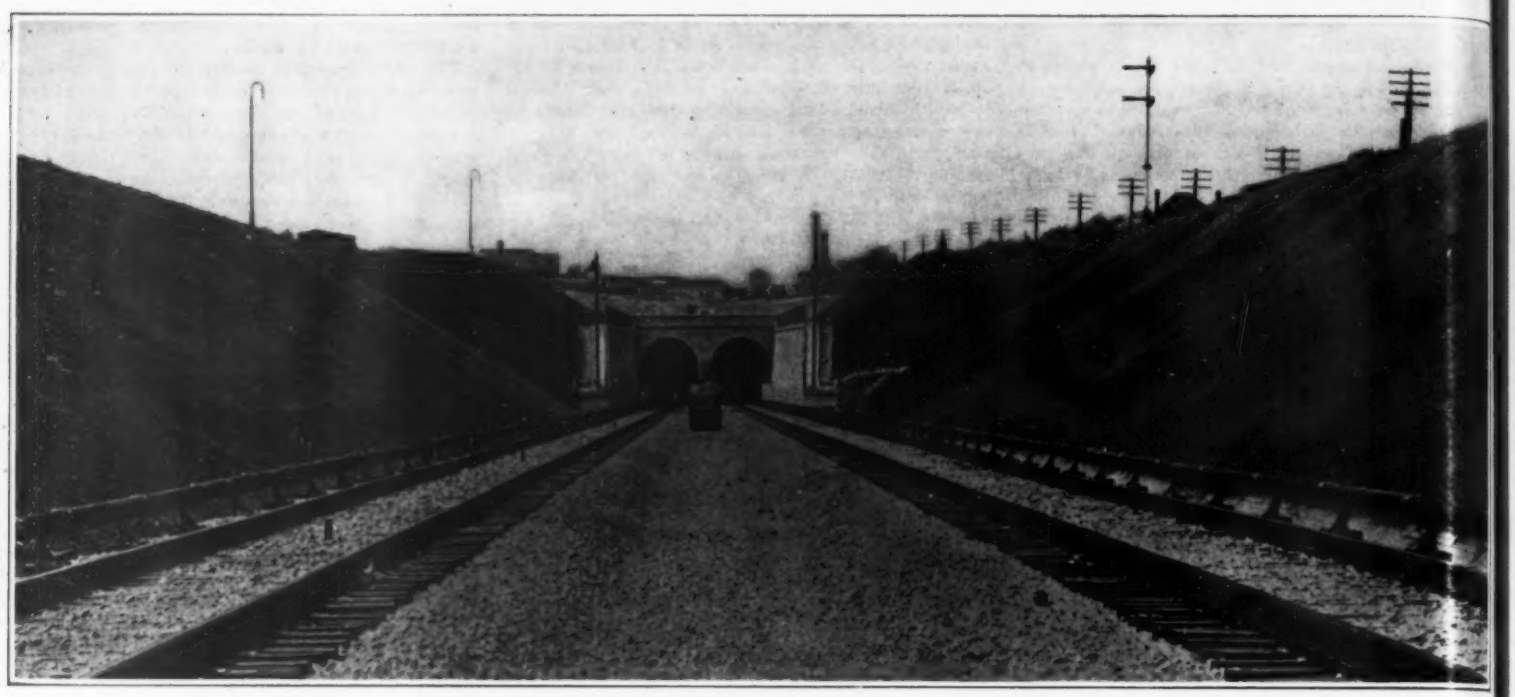
Bulgaria also has an outlook on the Black Sea. Sixty years ago the name of Varna was familiar enough to English ears, for there was the base of the Crimean Expedition. Varna passed from Turkey to Bulgaria under the Treaty of Berlin. As a port it has considerable natural advantages. Its situation at the head of a deep bay affords protection from the dangerous northeasterly gales of the Euxine. Great efforts have been made for its development. Twenty years ago all traffic was worked by lighters. Now there are quays with 25 feet of water alongside, and a million tons of shipping use the port in a year. Trade is chiefly in cereals. Varna has a population of 45,000 people and is the third town in Bulgaria, for which it serves not only as port, but as chief watering place.

The other port on Bulgaria's Black Sea coast, Bourgas, is of much less importance. Its bay is even better protected by Nature than that of Varna, and something has been done to improve the situation. But at present Bourgas is only about a quarter of the size of the more famous port. We have, of course, to remember that since the last Balkan war Bulgaria has a window upon the Ægean as well as the Black Sea. Its own Ægean port, Dedeagatch, is however a small place, the trade of which has not responded to rather ambitious efforts at development. "Anchorage off shore; cargoes worked by lighters," sums up its importance. It is, however, in time of peace a port of call for the Messageries Maritimes steamers between Marseilles and Constantinople. Like Rumania, Bulgaria has the rudiments of a navy, a handfull of small craft.

The frontiers of Bulgaria with Serbia and Greece are, as we all know, matters of bitter dispute. Perhaps it would pass the wit of man to find a line which should perfectly divide Bulgar and Serb and Hellene. The existing frontiers do not, except in certain sections, follow any marked physical division. But the conformation of the country makes this impossible. The mountains decline to accommodate themselves to racial distinctions. In the extreme northwest—that corner to which attention is inevitably directed—the boundary between Serbia and Bulgaria is merely a small river, the Timok. The country beyond, on the Serbian side, is, however, difficult and mountainous.—*The London Daily Telegraph.*

Examination of Coking Coal

THE organic or active portions of bituminous coal, as they occur in unaltered form, are the portions that particularly affect its coking properties, but heretofore methods of analysis have not taken them into account in estimating the value of coal. It has now been found by the University of Illinois that phenol at 100 deg. Cent. will dissolve out certain constituents of bituminous coal in their natural state, a process that can be used quantitatively, and it is also learned that the extract is the vital constituent concerned in the coking of coal. These experiments were conducted by Messrs. Parr and Hadley, and are described in the University *Bulletin* of November, 1914.



The approach to the Detroit River tunnel from the Canadian side.

An Important Terminal Improvement

The Economic Value of a Great Engineering Work Demonstrated

One of the important engineering works of the country completed within recent years is the double tube tunnel under the Detroit River, connecting the American and Canadian divisions of the Michigan Central Railroad Company. Detailed descriptions of the work and the numerous difficulties successfully overcome, from an engineering standpoint, were made public from time to time during construction. The tunnel was opened for traffic in 1910, and has entirely superseded the use of ferry boats for transferring freight and passenger traffic across the river.

Sufficient time has now elapsed to fully test the estimates of the advocates of the plan as to the advantages it was believed would accrue from a materially reduced cost of handling traffic, and time saved in transportation.

Upon trunk lines with a fluctuating volume of traffic, there are usually one or more points which tend to limit the amount of business that may be handled economically upon the whole line. Such a place was the Detroit River ferry, over which all the through traffic of the Michigan Central had to pass, and as early as 1870, with this fact in mind, plans were made for relief from the limitations this method of transfer imposed. With the engineering facilities then available, a projected tunnel was found to be impracticable of construction because of the conditions in the river bottom which tests disclosed.

Various plans involving the erection of a bridge were discussed, but these were finally abandoned for the reason that the clearances demanded for lake vessels would have required a structure of such height it would have been necessary either to establish grades impossible of operation, or construct approaches of such great length that the cost would have been prohibitive.

The growing traffic and vexatious delays pressed for a solution of the problem, and in 1906, confronted with the necessity of making large additions to the ferry transfer equipment, a committee was appointed to study the situation, and it reported that a tunnel could be built within reasonable limits of cost, and that in operation it would be economical enough to justify the investment. Plans were then adopted for the laying of twin tubes under the river, and as a necessary adjunct thereto, provision was made for a new passenger station in the city of Detroit and for new yards and terminals required by the change in location. Construction work was begun in 1906 and completed in 1910. The entire property, that is the Detroit River Tunnel Company, was capitalized at $21,000,000, and the money was spent for building and equipping the tunnel, rights of way, separation of grades at street crossings, new passenger station, yards and other terminal facilities.

Up to 1910 all trains were ferried across the Detroit River, requiring the breaking up of through trains and involving many switching movements, and a delay of from three to eight hours per train in through freight service. On account of the swift current in the river, the frequent use of the channel by steamships, and the added difficulties of fogs in the summer and autumn, and ice in the winter, it was found impossible to maintain schedules or to regulate traffic in a satisfactory manner.

Since the opening of the tunnel for operation the average time of passenger trains between Windsor and the new Detroit terminal, in either direction, is about nine minutes, or a less time than it formerly required simply to place the trains on the transfer boats.

The average time required for moving a freight train through the tunnel is about twenty minutes, as compared with several hours required for breaking up, switching, reassembling and ferrying trains under the former method of operation, in addition to which they were frequently subject to more or less serious delays crossing the river, due to weather conditions, ice, etc.

This saving of time has been particularly advantageous in the handling of traffic requiring expedited transit, such as perishable commodities.

The following statement indicates the growth in average monthly operating revenues since opening the tunnel:

THREE-YEAR MONTHLY AVERAGES.

	Monthly passenger and freight earnings:		Increase
	1907-1909.	1912-1014.	Per Cent.
Summer months.....	$2,127,675	$2,630,028	23.61
Winter months.....	1,964,946	2,464,694	25.43
Average throughout period.....	$2,046,311	$2,547,361	24.49

Electric tractor used in the tunnel.

Just how much of the increased traffic represents a normal growth and how much comes from the better service cannot be ascertained.

Besides the benefits resulting from the construction of the tunnel, a feature of equal importance, particularly from the railroad viewpoint, is the fact that the total cost of transfer is now considerably less per car than it was under the old method of ferrying across the river. Although the investment in the tunnel property and equipment is about eight times as large as that required for the transfer boats and slips, the cost of stitching and operating the trains and maintaining the property is so much lower that the higher interest charges and taxes are more than offset.

A material saving has also been obtained by the transferring to the new freight yards at Windsor, constructed for this purpose, of all the switching operations necessary on through freight trains, thus relieving the Detroit yards (which were rapidly becoming congested and overcrowded, owing to the extraordinary industrial growth of Detroit), and increasing their capacity about 40 per cent. Another item, the exact amount of which cannot now be computed because of the loss of records by fire, is the saving in per diem charges on loaded and empty freight cars, particularly empty cars, many of which were formerly frequently held back on either side of the river as a matter of necessity, in order that the forwarding of loaded cars might be expedited. Under present conditions, there being no congestion at this point, empties are forwarded without delay.

At the present time the traffic through the tunnel represents but a small percentage of its capacity. If traffic continues to increase in the next few years as it has in the past decade, the tunnel will be an increasingly valuable asset.

Solving the Potash Problem

Several new methods of increasing the supply of American potash have recently been brought to the attention of the Bureau of Foreign and Domestic Commerce of the Department of Commerce. One of the most promising of these efforts to find a substitute for German fertilizers is a patent taken out a few weeks ago by a Canadian for a method of using the potash in ordinary feldspar.

The process is a simple one, consisting of heating the feldspar with limestone and iron oxide at a temperature of about 2,200 deg. Fahr., which produces a partly fused mass that is easily decomposed by a weak acid. From this product the potash salts can readily be extracted for further purification. The inventor has been in consultation with Dr. Norton, the expert who has been looking after the potash and dyestuff situations for the Bureau of Foreign and Domestic Commerce, and it seems very possible that a greatly simplified method of transforming feldspar into fertilizer will soon be available.

A practical try-out for another method of obtaining potash fertilizer will soon take place at a New Orleans distillery where molasses is used in large quantities. It is a fact that 106 tons of potash are wasted daily by the twenty-five or more distilleries in this country that subject molasses to processes of fermentation. The New Orleans company is planning to install the process of saving the potash in distillery waste, recently brought to the attention of the public by the Bureau of Foreign and Domestic Commerce. It should be possible to make fertilizer from this otherwise worthless material at a price that will meet competition even after the war is over.—*U. S. Department of Commerce.*

Gunnery Aboard Ships*

Difficulties of Aiming and Factors That Affect the Accuracy of Fire

THE accuracy of modern artillery fire is the result of centuries of systematic experiment, combined with theoretical considerations of mathematical and physical nature. The estimation of the effect of air resistance, which shortens the projectile's flight and, in conjunction with the customary right-hand rifling, causes it to deviate toward the right, is made more difficulty by the variation of that resistance with temperature, humidity, barometric height, force and direction of wind, and other atmospheric conditions.

The gun is adjusted for range by means of a vertical sector attached to the pointing apparatus, and the allowance for deviation is made by turning the sighting axis away from this vertical plane by an amount which varies with the range.

The difficulties of aiming are greatly increased at sea where, as a rule, both gun and target are in motion. When a shot is fired from a moving ship a component, equal and parallel to the ship's velocity, is added to the velocity of the projectile. Hence, a shot aimed directly at a fixed point bearing perpendicular to the ship's course would go forward of the mark by an amount increasing with the ship's speed and the time of flight.

A shell discharged from a Krupp 12-inch gun, with a muzzle velocity of 2,500 feet per second, travels about 3¾ miles in 10 seconds, in which time the ship, if making 25 knots, moves 420 feet. At this range, therefore, the gun should be aimed at a point 420 feet in front of the point of attack. This is done by adjusting the sighting telescope to the proper divergence from the axis of the gun, and then directing the telescope upon the object of attack.

A shot fired directly forward from the bow is not deflected by the forward motion of the ship, but it overshoots the mark by a distance equal to the travel of the ship during the time of flight, e. g., by 420 feet with the gun, range and speed of the example cited. A shot fired directly astern falls short by an equal amount. The ship's motion affects both the range and the direction of oblique shots, as is illustrated in Fig. 1.

When the target also is in motion the problem is still further complicated, although it is simplified in one special case. In a "running fight" between two vessels of equal speed the conditions are the same as they would be if both vessels were stationary. An allowance must be made for any difference in the speed of the vessels and, if they are moving in opposite directions, the correction must be based on the sum of their speeds. In either case, the relative velocity forms the basis of the correction.

To the difficulty of determining distances at sea are added those of estimating the time of flight of a projectile, the angle between the line of fire and the ship's course, and the speed of the vessel attacked. The problem of aiming becomes very simple when the ship moves in a circle about a hostile vessel that is unable to move, for many shots can be fired with almost no change in the position of the gun, once correctly aimed. The enemy, on the other hand, is compelled to take aim afresh for every shot.

When the ship "lists" or "heels" in consequence of unsymmetrical loading or the flooding of injured compartments on one side, an effective broadside may still be delivered by altering the elevation of the guns, but in fore-and-aft or oblique fire the axis of the gun and the course of the projectile suffer a lateral deviation. This difficulty may be overcome by turning the vessel sharply so as to produce a compensating list toward the opposite side. The effects of a list upon broadside and fore-and-aft fire are illustrated in Fig. 2.

Far greater difficulties are introduced by the incessant oscillations of the vessel, which are known as rolling and pitching. The efficiency of a warship depends very much on the slowness and smallness of these oscillations. Rolling is a regular oscillation from side to side and is generally slower in large vessels than in small ones. Its amplitude may be diminished by the employment of bilge keels, which are flat strips about 20 inches wide, extending fore and aft along the vessel's sides, under water. (*S*, *S*, Fig. 2.)

They reduce the speed by one quarter to one half knot and do not prevent the roll attaining a maximum of 30 degrees, in unfavorable conditions.

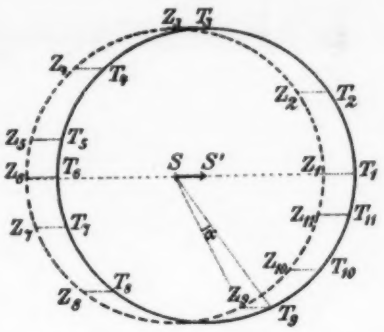


Fig. 1.—Firing from a moving ship. S, S', ship's motion during projectile's flight; Z, point aimed at; T, point hit.

Pitching is an oscillation about the transverse axis, the bow alternately rising and sinking, often so violently as to submerge it and seriously strain the vessel. The oscillation is increased by overloading the bow and stern, and for this reason the heavy guns are massed amidship as much as possible. The best arrangement of the guns, with maximum freedom of action, is attainable only in oil-burning vessels, which need no smokestacks.

Suppose a warship with its engines stopped and rolling moderately five times per minute is attacking a motionless vessel 102 meters (335 feet) in length (*E E'*, Fig. 3). If a gun is aimed at the point *O* the line of sights will move up and down along the line *A A'*, passing the middle point *O* with maximum velocity. If the gunner's impulse to fire comes at the instant when the sights are moving through *O*, the shot leaves the gun about one fifth second later, this interval being occupied in transmitting the impulse to the gunner's hand, pulling the cord, exploding the charge and carrying the shot from the breech to the muzzle. Meanwhile the gun has moved so that the shot passes through the point O_1 beneath, or the point O_2 above, the hull of the hostile vessel. In the latter case some part of the superstructure may be hit, hence it is advisable to aim at a point directly beneath an important part and to fire when the gun is swinging upward. It is still better, however, to make the point of attack coincide with the lowest point of the arc of oscillation, by depressing the gun until it points to the hull when it is moving least rapidly, at the bottom of its course, and by firing at that instant. In the diagram such a point of attack is indicated by *B*, and the arc of oscillation by *B B'*. In this case a shot fired two seconds two late might hit a mast or a smokestack. In reality the arc, and consequently the maximum velocity, of the oscillation are much greater than the diagram assumes, and the advantage of firing at the moment of minimum velocity is proportionately increased.

The interval between successive shots, in our example, is 6 or 12 seconds, according as the gun is fired in its mean or extreme position. Hence, if the hostile vessel, 102 meters long, is moving with a speed of 12 knots, equivalent to 6 meters per second, it can be hit only twice or thrice in the first case, and only once or twice in the second case, without re-pointing the gun.

If the attacking ship is moving with a speed of 12 knots the sighting point moves over a motionless enemy in the sinuous line *C C'* (Fig. 3), in which the peaks are 72 meters, and the median points are 36 meters, apart. In this case also two or three hits may be made by firing in the mean position, and one or two hits by firing in the extreme position of the gun. If the two vessels are moving in the same direction with equal velocities the conditions are the same as if both were at rest, but if the ships are moving in opposite directions, each with a speed of 12 knots, it is impossible to make two hits and difficult to make one hit with the gun in the preferable extreme position. With greater speeds the conditions become still worse. Hence, a decisive combat between two well-matched warships usually takes the form of a "running fight."

In fore-and-aft fire the rolling of the ship causes the sighting point to oscillate in an arc *D D'* (Fig. 3) and affects at once the direction, elevation and range of the shot. The gun may be adjusted to bring the middle point of this arc on the enemy's hull, at *O*, and fired when it passes this point with its maximum velocity, or it may be set to bring the ends of the arc, *E E'*, on the hull and fired when it is at these points and moving very slowly.

In oblique fire the line of oscillation lies between *A A'* and *D D'* when both ships are stationary, and becomes an inclined wave-line in the case of relative motion.

The oscillations due to pitching are similar to those caused by rolling, but smaller and of different period. The combination of the two oscillations causes the sighting point to describe a so-called Lissajous' curve, of which two very simple varieties, corresponding to vibration ratios of 1:3 and 2:3, are shown in Fig. 4. In most cases the figures are so intricate that it is impossible to lay down general rules for finding the best moment for firing. Relative motion of the vessels introduces additional complexity. In gunnery, as in billiards, no amount of theoretical knowledge can take the place of the skill and insight developed by practice.

High angle fire is useless aboard ship, because the range is greatly affected by small changes in the inclination of the gun, and even a small difference in range is very important. A smokestack may be destroyed by a level shot that overshoots its mark by 100 yards, but a few yards' error in range may cause a high angle shot to fall harmlessly into the water (Fig. 5).

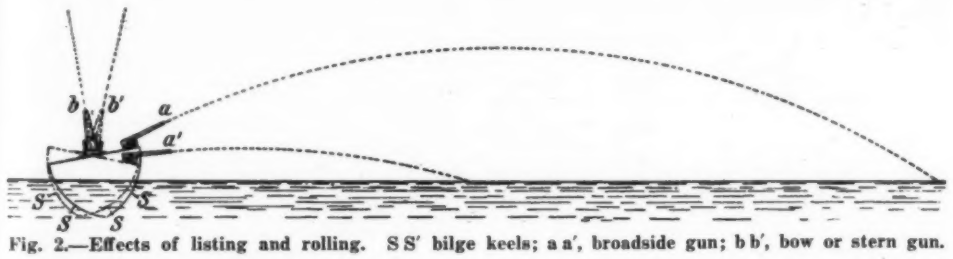


Fig. 2.—Effects of listing and rolling. S S' bilge keels; a a', broadside gun; b b', bow or stern gun.

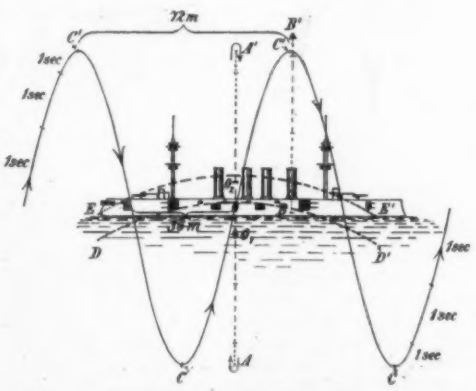


Fig. 3.—Oscillations of sighting point caused by rolling.

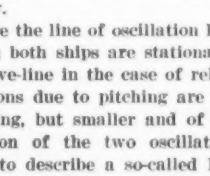


Fig. 4.—Lissajous' curves.

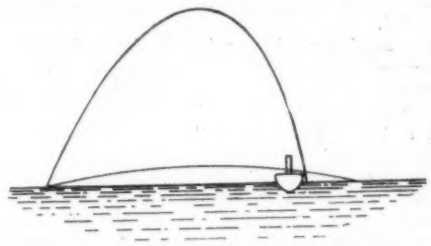


Fig. 5.—Areas covered by level and high angle fire.

* An abstract of Prof. Adolf Keller's article in *Prometheus*. Translated for the SCIENTIFIC AMERICAN SUPPLEMENT.

Metallurgical Smoke*

What It Is and Some Methods of Prevention

One of the first matters to receive attention from the Bureau of Mines when it was authorized to undertake investigations relating to wastes in the mineral industries was the smoke problem at smelting and ore-roasting plants.

Metallurgical smoke causes considerable friction between the metallurgical industry and agriculture in certain parts of the country. Owners of smelting plants are making every effort to devise ways and means to do away with possible damage and annoyance from smoke and are meeting with success. The problem is peculiarly difficult in this country because of the large tonnages of material that must be handled. The solution of the problem is not yet at hand and much work still remains to be done.

At some plants the amount of metallurgical smoke is very great, exceeding in weight that of the solid material charged into the furnaces. Thus, in pyritic smelting, 1 ton of furnace charge requires approximately 1.2 tons of air to smelt it and gives rise to 1.4 tons of metallurgical smoke or furnace gases. Also, the volume of this smoke in the highly heated condition (400 deg. Cent.) in which it is discharged from the furnace is very large. In the instance cited it is about 71,620 cubic feet per ton of charge. As an example of the tremendous amount of metallurgical smoke produced by a large smelting plant, data regarding the Washoe smelter at Anaconda, Mont., are given. That plant, which produces about 300 tons of copper a day, has a stack 30 feet in internal diameter at the top, which discharges 1,341,000,000 cubic feet of smoke per 24 hours, as measured at standard pressure and temperature. The smoke contains about 1.734 per cent by volume of sulphur-dioxide gas, or 23,252,940 cubic feet per 24 hours, which is equivalent to 2,092.7 tons, and, if converted into sulphuric acid, would yield 3,427 tons of acid, with a specific gravity of 66 degrees Baumé, or about one third of the total production in the United States.

The volume of smoke discharged from the top of a stack is, of course, decidedly larger than that discharged at the throat of the furnaces of the plant, for in its passage through the dust chambers and flue system the smoke mixes with air that filters in accidentally or is purposely admitted.

Metallurgical smoke consists of three distinct substances—the gases, the flue dust, and the fume. Of these three consituents the gases make up the great bulk. They come from the air used in the furnace to burn the fuel and also from chemical reactions between the oxygen of the air and certain constituents of the charge. The most abundant gas is nitrogen, derived from atmospheric nitrogen, which passes through the furnaces unaltered. It constitutes usually from 60 to 87 per cent of the bulk of metallurgical smoke. The gas ranking next in importance is carbon dioxide, which is produced by the combustion of carbon. The proportion of this gas ranges from about 3 to 5 per cent in pyritic smelting to about 15 to 20 per cent in lead blast-furnace smelting, being between these figures for other blast-furnaces and reverberatory-furnace smelting. Gases from furnaces for roasting sulphide copper ores usually contain only significant amounts of carbon dioxide, but those from furnaces roasting lead ores and gold and silver ores in which carbonaceous fuel is burnt contain appreciable amounts of it. Carbon monoxide, a very poisonous gas, is not present to any degree in metallurgical smoke arising from the treatment of lead, copper, gold, and silver ores, the only exception being the gases from lead blast-furnace smelting, in which, on account of the considerable amount of fuel used, 5 to 10 per cent of carbon monoxide is found. Otherwise, the content of carbon monoxide rarely exceeds 1 per cent and sometimes is much less, none at all being present in gases from pyritic smelting and from certain roasting furnaces.

The gases so far discussed are the constituents of smelter smoke that cause no complaint and are the same as those that issue from the ordinary boiler stack. Sulphur dioxide is the constituent that largely gives smelter smoke its annoying properties, and requires special attention in order to be rendered innocuous.

In both roasting and smelting furnaces the sulphur dioxide is from the combustion of the sulphur in the sulphide minerals of the ore charge. The proportion of the gas in metallurgical smoke varies widely. The maximum amount of sulphur dioxide is found in the gases from pyritic smelting, where it constitutes 4½ to 9 per cent by volume of the smoke issuing from the furnace throat. In partial pyritic copper smelting the gases contain 2 to 3½ per cent of sulphur dioxide. The gases from the roasting of sulphide copper ores contain about 2 to 2.75 per cent, and may contain more. Gases from from reverberatory smelting furnaces contain usually less than 0.5 per cent of sulphur dioxide, except in the early stages of smelting, during charging. Gases from lead-smelting furnaces and from the roasting of ores, not mentioned above, contain smaller proportions, usually less than 1½ per cent. These figures refer to the gases as discharged from the furnaces. Before the gases pass off into the atmosphere from the stack, they are usually considerably diluted. Formerly metallurgical smoke containing 1.5 per cent and more of sulphur dioxide was frequently discharged from stacks at some plants, but at present, in consequence of a number of court decisions, this proportion is reduced by dilution before the smoke reaches the stack. Some recent court decisions have fixed the amount of sulphur dioxide that may be discharged from stacks in certain districts at not more than 0.75 per cent.

Another gas found in metallurgical smoke, as it issues at high temperature from the furnaces, is sulphur trioxide or sulphuric anhydride. This substance, when combined with water, molecule for molecule, forms common sulphuric acid. It is formed in furnace operations by the oxidation of sulphide minerals, although in comparatively small amounts under most conditions, and if the temperature be high enough, the gas is found in the discharged gases, uncombined with water or with metallic bases, as sulphur trioxide. As the gases cool it combines with water, present in the metallurgical smoke as steam, to form sulphuric acid which, when the temperature becomes low enough, finally condenses. In this way sulphur trioxide in smelter smoke becomes an exceedingly harmful substance, one that may do a great deal of damage. Fortunately, however, it is present only in small proportions and, unlike the true gases, can be, and in most instances is, removed from the smoke before it is discharged into the atmosphere. Usually gases from blast-furnace smelting of copper and lead ores contain insignificant amounts of sulphur trioxide, but gases from roasting furnaces may contain appreciable proportions. Thus, for instance, gases from the roasting of sulphide copper ores may contain 0.25 to 0.75 per cent of sulphur trioxide. Aside from the gases mentioned, metallurgical smoke contains considerable water in the form of steam and occasionally small quantities of hydrocarbons and other gases.

The flue dust that is carried by the gases as they issue from the furnaces consists of small particles of the different ores, fluxes, or fuel. The gases, on account of their high velocity, entrain these fine solid particles, and when the velocity is reduced in the dust chambers the particles settle. The amount of flue dust made in different smelting operations varies greatly, depending on such factors as design of furnace, fineness or coarseness of the ore charge, blast pressure or draft employed, and working condition of the furnace. Estimated on the basis of the tonnage of charge that is smelted, it may range from a fraction of 1 per cent up to 10 per cent of the weight of the furnace charge. Thus, in copper blast-furnace smelting at the Copper Queen mine in Arizona, 1 ton of flue dust was produced for every 17 tons of charge, or 5.55 per cent. In some instances, it is convenient to express the amount of flue dust in metallurgical smoke in the manner that iron metallurgists state the content of dust in blast furnace gas, that is, in grains (weight) per cubic foot of gas. This manner of expressing the dust content of the smoke stream is particularly applicable after the settling of the coarser particles.

Generally speaking, the composition of the flue dust is similar to that of the ore charge of the furnace. However, it may be modified by some contituents of the charge being finer than others and thus producing more dust. Flue dust is usually considered a troublesome product, for its treatment is rather difficult and expensive, although a number of successful methods have been devised. Flue dust varies in size from 0.25-inch to 0.125-inch particles of the lighter material down to an extremely fine dust resembling impalpable powder. No matter what its size, however, true flue dust is to be considered as composed of original particles of the ore charge, either unaltered or chemically changed.

Related to the flue dust and in part recovered with it is the fume. Sometimes no distinction is made between fume and flue dust, for in copper smelting the amount of true fume is relatively small although certain plants treating arsenical ores make considerable fume. In lead smelting, however, considerable amounts of fume are produced. The fume consists of the volatile constituents of the ore charge which pass off in the form of vapor with the gases from the furnaces and then sublime into minute solid particles in the cooler part of the flues. In examining the dust chambers and the flue system of a smelting plant, it will be noted that a fine gray-white impalpable powder is deposited on the walls, roof, and floor of the flues near the stack end of the flue system, the amount being greatest near the stack and diminishing as the furnace is approached. In certain sections of the flues and chambers this fume is mixed with the fine flue dust.

On chemical examination, the fume is found to consist largely of lead compounds—such as the sulphate, sulphide, and oxide—arsenious oxide, antimony oxide, zinc oxide and zinc sulphate, elemental sulphur, and small amounts of the oxides of tellurium and selenium. In general, all the volatile constituents of the ore charge are represented. The fume frequently contains appreciable amounts of silver, which is markedly volatile under certain conditions. The particles of fume are very fine and are under the stress of certain physical forces, so they do not settle easily, as most of the flue dust does, but in large proportion pass through the stack with the gases and spread over the surrounding country, unless special preventive methods are applied, as is now generally done.

When zinc minerals are present in the furnace charge, sulphur trioxide is rendered harmless in so far as the formation of sulphuric acid is concerned, as sulphur trioxide unites with zinc oxide to form sulphate of zinc, which is deposited with the fume. Lead minerals act similarly to zinc minerals, when the action in the furnace is oxidizing. The most harmful constituents of true fume, if allowed to escape from the stack, are sulphuric acid, lead compounds, and arsenious oxide. These substances settle on the surrounding country and under certain atmospheric conditions of moisture and wind may sufficiently concentrate to damage vegetation and injure animal life.

Most of the more modern metallurgical plants make ample provision for the recovery of fume from furnace smoke. Stacks from metallurgical works sometimes emit white or grayish-white smoke of varying degrees of density, from smoke that is barely visible to very dense smoke. In general one may state that it is the fume that renders metallurgical smoke visible, except when visibility is due to the condensation of water vapor on cold days. The true gases in metallurgical smoke are invisible.

From the foregoing statement it is evident that metallurgical smoke contains three distinct types of constituents—gases, flue dust, and fume. Of these, all the true gases escape from the stack, and all but the very finest flue dust may be settled out by ample and properly designed dust chambers. The fume is only partly recovered with the flue dust even by the use of elaborate dust chambers and flues; special apparatus must be erected to recover it.

It is apparent that the harmful constituents of smelter smoke are: (1) Sulphur dioxide gas, (2) sulphuric acid formed from sulphur trioxide generated in the furnaces, (3) fume or fine solid particles containing lead and arsenic compounds and acid sulphates.

The most important of these at the present time is sulphur dioxide, for no universally applicable method of eliminating this gas from smelter smoke is as yet in commerical use. Sulphur trioxide and sulphuric acid in their behavior may be classed with true fume, and methods can be used that will completely eliminate these substances from the smoke before it is discharged into the atmosphere.

Sulphur dioxide is an invisible gas with a highly characteristic penetrating and pungent odor familiar to almost everyone. It is stated that air containing 0.007 per cent by volume of this gas is unbreathable, the gas not having a toxic effect but causing a spasmodic contraction of the air cells of the lungs. Only very small proportions of the gas are ordinarily present in the atmosphere, but measurable quantities are invariably found in the air of cities, especially manufacturing centers where much coal is burned, being formed by the combustion of the sulphide minerals in coal, all coal containing some sulphur. As an example of the quantity of sulphur dioxide in the air of cities, the following examples are given: Berlin, 0.000035 per cent by volume; London, 0.00039 per cent; Glasgow, 0.00042 per cent. Air in the vicinity of Salt Lake City, Utah, contained from 0.001 per cent to none.

The gas may be detected in the air by its smell if present in the ratio of more than one part to 150,000 parts of air. Chemically, it may be readily detected in the air when the proportion present is more than one part per million. It is probable that the sulphur dioxide of the air is slowly converted into sulphuric acid by the action of the oxygen and the water vapor in the air, and is finally precipitated with the rain or snow.

The prevention of damage to vegetation by sulphur

* Extracts from *Bulletin* 84, of the Bureau of Mines, by Chas. H. Fulton.

dioxide in the atmosphere needs the close study of disinterested scientific observers. It is probable that the question will be prominent for some time, as the elimination of sulphur dioxide from smelter smoke seems to be in the far future, and the amelioration of conditions depends at present on diluting the smoke until the sulphur dioxide content is so small as to be harmless. This in itself is a great engineering problem for large plants. The point to which dilution must be carried no doubt depends upon the nature of the vegetation in the vicinity of the plant, the climate, whether wet or dry, and the season of the year.

That comparatively small amounts of sulphur dioxide and sulphuric acid (it must be borne in mind that sulphur dioxide is probably slowly converted into sulphuric acid in the atmosphere) do harm to vegetation is attested to by an examination of the trees in large industrial cities. These, although in many instances seemingly healthy, suffer from sulphate poisoning and lose their leaves much earlier in the Fall than other trees in the vicinity not subject to the contaminating atmosphere.

At European plants the amount of sulphide ores smelted, and hence the volume of fume discharged from furnaces there, is small as compared with those at plants in this country. Moreover, methods for handling smoke that are satisfactory for small operations are inadequate and unsatisfactory for large-scale work. For example, relatively small amounts of smoke may be put through a washing process and most of the deleterious constituents removed, but such washing is impracticable for very large volumes of gas. Even in European countries where it would seem that the question might have been settled long ago, contention between metallurgical and agricultural interests is not infrequent. Evidently the problem is difficult to solve in a satisfactory manner.

The damage that smoke can do depends largely on climatic conditions, especially the relative humidity of the atmosphere. The damage is much greater in regions having a moist than in those having a dry climate.

It is unnecessary to discuss the properties of the smelter-smoke gases—carbon monoxide, carbon dioxide, nitrogen, and oxygen—as these have no particular bearing on the problem in hand.

In some of the older plants of this country the velocity of the smoke stream in the flues was frequently more than 30 feet per second, with the result that the stacks emitted a considerable quantity of true flue dust which was scattered broadcast in the vicinity of the plant, doing damage. The more modern plants do not, however, have such high velocities in their flues and little true dust is discharged from their stacks..

If the smoke stream be conducted through dust chambers of correct cross section and length, the dust will settle satisfactorily. Although formerly it was the practice to maintain a velocity of gas in dust chambers and flues as high as 30 to 40 feet per second, the speed now commonly accepted as proper for the smoke stream in dust chambers is 2½ feet per second in plain chambers and 5 feet per second in chambers hung with wire baffles. The length of dust chambers must be sufficient to give the dust an opportunity to settle.

Only a part of the true fume can be removed by a reduction of the velocity of the gas stream, even with proper cooling so as to precipitate the fume.

A modern flue system, therefore, may be considered to consist of (1) the individual flues leading from the different furnaces and of such cross section that the gas velocity shall not exceed 20 to 25 feet per second, the flues discharging in a proper manner into (2) a large chamber known as the dust chamber 250 to 350 feet long and of such cross section as to reduce the gas velocity to 2½ or 5 feet per second, dependent upon whether wire baffles are used, and (3) a flue connecting the dust chamber with the chimney and of such cross section that the gases have a velocity not exceeding 20 or 25 feet per second, and (4) a chimney of sufficient cross section to carry the gas stream at this velocity and of sufficient height to give ample natural draft at the furnaces.

There are at present two methods employed for the recovery of fume—filtering the smoke stream through woolen or cotton bags and electrically precipitating it by the electrical precipitation process. The first has a rather wide application; the second is just beginning to be used but gives great promise. In general it may be stated that fume will be removed from smelter smoke for two reasons: First, because the fume is valuable and its recovery is profitable, as in a number of instances in lead smelting; and, second, to remove noxious material, such as lead compounds, arsenious oxide, and sulphuric acid, from the smoke stream and to prevent its discharge into the atmosphere, where it will do damage.

Practically all lead-smelting plants in this country, except a number in Colorado, are provided with bag houses. The maintenance of a bag house is expensive, and its use is profitable only when smelting in the blast furnace with a high percentage of lead on the charge is being done. Hygienic and legal reasons, however, make its use at lead smelters practically imperative. The fume from a copper smelter is usually not as valuable as that of a lead smelter, so that a bag house for its recovery is even less likely to yield a profit. Furthermore, as regards copper smelters, the temperature of the gases is high and their volume is much greater than in lead smelters, so that the technical difficulties of bag-house operations are greatly increased. Hence, the bag house is rarely considered as an adjunct to the copper smelter.

The bag house consists essentially of two chambers, the lower or dust chamber being 12 to 16 feet from floor to ceiling, the upper or bag compartment being 30 to 40 feet in height. The walls and partitions are usually of brick, properly buttressed or held together by tie rods. The dust chamber or smoke cellar is divided by brick partitions into as many compartments (called bays) as there are flues leading to the bag house, thus enabling a part of the bag house to be shut down for cleaning out the collected fume without interfering with the rest of the house. The ceiling of the smoke cellar is made of iron or steel plate and is provided with a number of thimbles or rings projecting into the bag compartment. From the supports near the top of the building cotton or woolen bags are hung, and the lower ends of the bags are tied to the thimbles by means of twine, wire, or hoop bands provided with strap clamps. Each compartment of the bag house has a stack to carry the filtered gases some distance into the air. Fans capable of moving 150,000 to 250,000 cubic feet of gas per minute force the smoke stream with its fume and fine flue dust through a number of large conduits into the smoke cellars and through the bags, the solids being removed so perfectly that the discharge from the stacks is invisible.

The ordinary bag house is provided with 3,000 to 4,000 bags, each bag being about 18 inches in diameter and 30 to 33 feet long. It is usual to provide 300 to 500 square feet of filtering area for every ton of charge smelted in the blast furnace, or about 3.42 square feet per cubic foot of smoke stream per minute.

The precipitation of suspended matter, whether in gases or liquids, may be accelerated by electricity in the form of either direct or alternating current. Where an alternating current is applied the action consists for the most part in an agglomeration of the suspended particles into larger aggregates and a consequent more rapid settling of these aggregates under the influence of gravity. The application of the alternating current, however, is effective only when the masses of gas or liquid to be treated are fairly quiescent and a simple agglomeration of the suspended particles into larger aggregates is sufficient to effect separation by gravity. As regards large volume of rapidly moving gases, such as occur in smelter flues, the agglomeration and settling process induced by the alternating current is too slow, even when the flues are expanded into large dust chambers. Consequently, the application of the direct current, the action of which is quite different from that of the alternating current, is necessary.

If a needle point connected to one side of a high-potential direct-current line be brought opposite a flat plate connected to the other side of the line the air space becomes highly charged with electricity of the same sign as the needle point, irrespective of whether this is positive or negative. Any insulated body brought into this space instantly receives a charge of the same sign. If this body is free to move as is a floating particle, it is attracted to the plate of opposite charge and will move at a rate proportional to its charge and the potential gradient between the point and the plate. Even if there are no visible suspended particles, the gas molecules themselves undergo this same process, as is evidenced by a strong wind from the point to the plate, even in perfectly transparent gases. The familiar experiment of blowing out a candle flame by presenting it to such a charged point is another illustration of the same phenomenon. The gas is ionized and some of the ions collect upon the solid particles, thereby charging them electrically. As the charged particles are within a strong electric field of constant polarity, they are driven to the collecting electrodes.

The question as to whether sulphur dioxide or the solids and sulphuric acid discharged as fume are the chief cause of damage has been widely discussed. There is, however, no question but that both have caused damage. Lead-smelting plants discharge gases that on the whole are comparatively low in sulphur dioxide, and it is probable that damage formerly caused by the smoke stream from such plants was due in large part to the solids. In copper smelting the sulphur content of the furnace charges is much higher, and it is probable that such damage as has been done was largely due to sulphur dioxide. Therefore much effort has been directed toward finding methods for the removal or destruction of this substance, but, to the present time, with little promise of success. The amount of sulphur dioxide discharged daily by all the smelting plants of the country is enormous, and the utilization of all of it in some form, such as sulphuric acid or sulphur, is at present not feasible, as the amount of these substances produced would many times supply the possible market demand.

The Hall and the Thiogen processes, now prominent in the amelioration of the smoke difficulty, are designed to remove sulphur from the smoke stream in the form of elemental sulphur. The Hall process eliminates the sulphur in the ores direct in the form of elemental sulphur and prevents the formation of sulphur dioxide; the Thiogen process destroys the sulphur dioxide in the smoke stream, with the production of elemental sulphur. The leading idea here also is the winning of a valuable by-product, which will yield a profit or at least meet the expense of the applied process. Elemental sulphur at present has a ready market, but it is easy to show that the possible production of sulphur by these means will glut the market. The problem is again a local one.

If the sulphur dioxide in smelter smoke cannot be converted into valuable by-products, the problem becomes one of finding a cheap means to destroy the sulphur dioxide and convert it into a harmless substance. From this standpoint, although for obvious reasons the sulphur dioxide may not be converted into sulphuric acid, it might still be converted into elemental sulphur, which could be stored in isolated places. At various times many suggestions have been made for the destruction or removal of sulphur dioxide, such as its removal by solution in water or its absorption by limewater, with the formation of lime sulphite, all of which, except under certain local conditions when they may become applicable, in the end give rise to just as great a nuisance as does the original substance. At present the best-known method for minimizing the nuisance of sulphur dioxide in smelter smoke is to dilute the smoke and diffuse the dioxide to such an extent that it will be practically harmless.

The dilution of smelter smoke by air to such a point that the concentration of sulphur dioxide is low enough to be considered harmless appears at present the only universally applicable remedy for the sulphur dioxide nuisance. Although this fact is generally known and its significance is fully realized by metallurgists, it would seem that in a number of instances the possibilities of the method have not been fully utilized.

It was formerly rather generally believed that if smelter smoke was discharged from high chimneys natural diffusion would so act on the smoke stream that when the gases reached the ground, the sulphur-dioxide would be so diluted as to be practically harmless. However, experience, both in this country and in Europe, does not warrant this assumption. It seems rather that the diffusive action is comparatively slow, and that frequently masses of smelter smoke are wafted to the surface, still in such concentrated condition as to be harmful. High stacks tend to protect the immediate vicinity around the smelting plant, and may cause a milder but widespread damage at some distance from the plant.

Recently the feasibility of diluting the smoke stream with air by the use of large fans and of then discharging the diluted smoke from a number of low stacks rather than from one high stack has received considerable attention.

The Look-Out for Submarines

It is widely recognized that, with an efficient look-out to detect the existence of a submarine in the neighborhood of a ship, effective measures can be taken against a successful attack by the torpedoes of such craft, either by immediate and rapid retreat from the vicinity, or, if there is reasonable prospect of success, by combating the submarine boat. It is true that the periscope offers a small point of observation, but this only increases the importance of a complete and sharp lookout. The difficulty is that, with the best of binoculars or telescopes, the movement of the ship disturbs the constancy of the observation. Even with the arms resting on the rail of the bridge, or of the gunwale, the movement of the ship is a disturbing element. Mr. John Gardner, of Fleetwood, the well-known inventor of the Gardner submarine signalling system, has devised a method which promises to overcome this difficulty, as he ensures that the observer, comfortably seated, with his telescope supported on a stand in front, can be certain that the telescope or binocular glasses will always be approximately parallel to the surface of the sea, irrespective of the movement of the ship. He achieves this end by mounting a pedestal securely to the deck, and on this is carried the seat, with the table to support the telescope or binoculars on a standard, and the seat and table are maintained truly horizontal relative to the sea surface by the operation of a gyroscope. Moreover, the platform, with seat and table, is automatically rotated slowly from left to right, and *vice versa*, by the utilization of the power for the gyroscope, so that the observer need only concern himself with keeping a sharp look-out within the field covered by the slowly-moving instrument. It will thus be seen that, irrespective of the movement of the ship, due to seaswell or waves, the lookout can scrutinize every part of the sea-surface within a radius compassed by the telescope in its movement to and fro.—*Engineering.*

Electricity is employed in the instruction rooms at German military barracks.

Electricity in Barracks

By Dr. Alfred Gradenwitz

In military buildings, especially those intended for the housing of soldiers, the many phases of routine work, as well as warlike purposes proper, electricity, of course, finds a most extensive scope.

The advantages of electric light are, for instance, realized so generally that this mode of lighting is being adopted at a steadily increasing rate in soldiers' dwelling rooms, kitchens, dining halls, guard-rooms, as well as for the illumination of court yards, vestibules and staircases. There has also been for some time a tendency to provide stables, riding schools, drilling halls, etc., with electric light. In ammunition rooms, on account of the great inflammability of the materials stored there, a fireproof electric lighting plant is the only source of light suitable for the case.

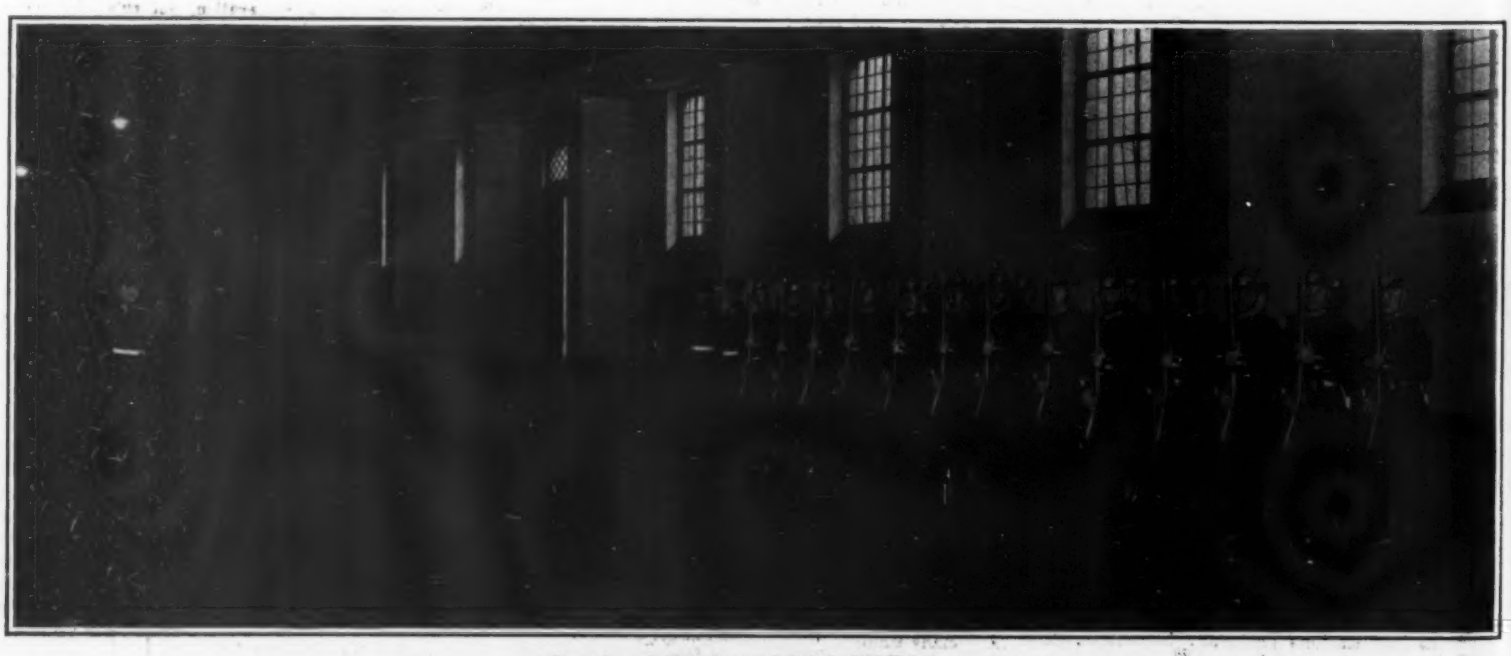
Apart from lighting purposes, electricity is used in barracks for ensuring an adequate aeration by means of electric fans, and for driving the various types of household machines employed in officers' and soldiers' kitchens (potato peeling, paste stirring machines, meat rams, etc.). Refrigerating machines, pumps for raising water, centrifugal machines, sewing machines, etc., are likewise operated by electricity.

However, the use of electric power transmission in military workshops is even more extensive. In fact, mechanical labor in German military joiners', tailors', shoemakers' and bakers' shops, in smithies, locksmiths' and farriers' shops, printing works, etc., is effected on an increasing scale by electrical operation. In every phase of the life of a soldier electricity has been applied most extensively.

Kavala, the Debatable Land

"The Greco-Bulgarian dispute hinges upon the rich tobacco country in and around Kavala." So Dr. Dillon wrote in August, 1913, when the negotiations preceding the treaty of Bucharest had reached a critical stage. By the unstable settlement which followed Greece secured what she claimed. The frontier between the two countries became the river Karasu or Mesta, so far as it runs north and south and farther north a prolongation of the same line. A year and a half later, in January, 1915, when M. Venizelos was working for the reconstitution of the Balkan League and its intervention on the side of the Allies, he was ready to secure the adhesion of Bulgaria by proposing the surrender to her of some part of the territory which he had demanded in 1913. It has been officially stated that the cession under consideration involved Kavala itself, some 2,000 square kilometers in the vicinity (772 square miles), and a Greek population of not less than 30,000 people.

These facts are sufficient to show that Kavala and the plains about it are a region to which both Greek and Bulgarian can make a plausible claim. The district is, in fact, essentially a debatable land. There is no natural frontier line between Slav and Hellene, no mountain range, no river following a racial cleavage. The welter of races which makes the division of Macedonia everywhere difficult is here inextricable. Greeks are probably in the majority, but the Bulgarian element is numerous. It follows that any frontier must be artificial, and, therefore, if it is to be permanent, a compromise which leaves neither race with sufficient motive for a war of



Capacious drill halls are brightly lighted.

German army stables are electrically lighted.

revenge and liberation, must be definitely established.

Kavala itself is a town of importance. The Messageries Maritimes boats from Marseilles to Constantinople make it a port of call. The traveler approaching from the sea looks upon a bold headland, with a small harbor on either side. Above the busy quays rises a long line of Oriental domes, and above that again a bluff line of rock cutting the town in half; on the sides of this scarp you see terraces of white houses studded with minarets. High over all stands a massive castle. As the steamer draws closer in you can make out a long aqueduct on two tiers of arches, which brings water to the city from Mount Pangaous. The mountain looms dark in the distance, and from it two sheer cliffs approach the sea.

The town has a good deal of historic interest. When it was called Neapolis St. Paul landed there on his way to Philippi. It was a place of importance in the days of the Byzantine Emperors, who built for it the great aqueduct. Even the Turks added something to its treasures, for in the great age of the Ottoman Empire a benevolent pasha presented Kavala with a vast and pictureque caravanserai. The town was the birthplace of that extraordinary adventurer Mehemet Ali, who began life as a smuggler, made himself sovereign of Egypt, and thence defied half Europe. It was he who built the line of domes, which you see from the steamer, and which house a charitable institution. With something of a shock you discover in Mehemet Ali a philanthropist.

The present population of the town is difficult to estimate. The provisional census of 1913 returns it at 45,000, but this is probably exaggerated. A large influx takes place during the summer months, when the tobacco harvest has to be dealt with and prepared for export. During the last complete year before the Balkan wars more than 12,000,000 kilogrammes of tobacco, that is more than £3,000,000 worth, passed through the warehouses and quays of Kavala. The economic importance of the place needs no further illustration.

The best of what we still call Turkish tobacco is grown in the district around Kavala. The country consists of plains backed by hill and mountain, and both the level country and the lower slopes of the upland are well watered and of extreme fertility. Before the break-up of the Turkish dominions it was estimated that the tobacco of Eastern Macedonia brought the exchequer of Constantinople a direct revenue of more than £400,000 a year. The value of the crop exported was more than £4,720,000. Not all of this, of course, was grown in the "debatable land" around Kavala. Even the frontier of the Treaty of Bucharest gave some of the tobacco area to Bulgaria. But by far the greater part has been in Greek hands, and the value of its possession is sufficiently obvious. Besides the predominant tobacco industry, the district also produces some cotton and carries a large quantity of stock. If it is not incongruous to link history with these commercial details, we may note in conclusion that on these fertile plains of the tobacco country stood Philippi, with its memories of Mark Antony and Brutus, and the affectionate last Epistle of St. Paul. The city now is but a mass of ruin among the fields.—*The London Daily Telegraph.*

Military riding school illuminated by electric lights to permit of practice at night.

The Indian and Nature*

The Basis of His Tribal Organization and Rites

By Alice C. Fletcher

From an extended study of the Siouan tribes of the Plains Indians, it is evident that their tribal organization and rites are based on concepts derived from observations of Nature.

These Indians belong to an observant, thoughtful, out-of-door people who for generations havel ived in intimate relations with an unmodified environment. No animal but the dog was domesticated, all creatures pursued their own mode of life. With few exceptions plants were uncultivated, undisturbed in their manner of growth. No highways broke through the prairies or woodlands, the winding trails of animals served as footpaths for man. There was nothing visible to suggest any break in the continuity of the natural relation between man and his surroundings. It was amid such untouched, unforced conditions that these people attentively watched the various phases of life about them and pondered deeply on what they saw.

The Indian discerned that everywhere dual forces were employed to reproduce and so perpetuate living forms. The fructifying power of the sun was needed to make the earth fruitful and only by the union of the two, the sky and the earth, was life in its various forms made possible. Upon these two opposites, he projected human relations and made them, to a degree, anthropomorphic, the sky became masculine, the earth, feminine. Finally, he was led to conceive of the cosmos as a unit, permeated with the same life force of which he was conscious within himself; a force that gave to his environment its stable character; to every living thing on land or water the power of growth and of movement; to man it gave not only his physical capacities but the ability to think, to will, to bring to pass. This unseen, undying, unifying force is called by the Omaha and cognate tribes, Wakonda. Through Wakonda all things came into being, are ever related, and, more or less interdependent. Consequently, Nature stood to the Indian as the manifestation of an order instituted by Wakonda wherein man was an integral part. To this order he turned for guidance when establishing those means, religious and secular, that would insure to him, individually and socially, safety and continuous life.

Finding himself to be one of a wide reaching family, the Indian planned his tribal organization upon the type of that family. He divided the people into two great sections, one to represent the sky, the other, the earth. Each of these sections was composed of a number of kinship groups, called by the Indian, To"-wo"-gtho", meaning village. (These villages are spoken of as clans or gentes by students of our race). Each village stood for some one of the forms of life seen in Wakonda's instituted order. The sky was the abode of the sun, the moon, the stars, the storm cloud with its thunder and lightning. The earth, with its land and water was the abode of the trees, the grasses, and the various animals so closely allied to man and his needs. The tribal organization aimed to mirror man's environment. The tribal rites were instituted to provide a means by which the people could approach the invisible power, believed to abide in Nature, for help, to secure food, safety and long life.

Each village (gens) had its own ceremony which was also a component part of the tribal rites, wherein all the villages (gentes) were thus represented. The ceremony of each village (gens) had a central subject, some form or force, having its abode in the sky or on the earth, and represented by a symbol. The name given to this symbol by the Omaha and cognate tribes, is I-ni-ka-shi-ki-the, a term composed of, I, by which; ni-ka-shi, a part of ni-ka-shi-ga, people; ki-the, make themselves; and means, that by which they make or designate themselves a people. (Students of our race have applied to this symbol the term "totem."). As has been shown, this symbol referred to one of the forms or forces belonging to Nature as instituted by Wakonda, therefore represented in the tribal organization and the tribal rites. The symbol had a sacred significance to the people of the village (gens) in whose ceremony it held the central place. It bound the people of the village (gens)together by a sacred tie, made them distinctive among the other villages (gentes) that composed the tribe, and, it was a link between the people of the village (gens) and the invisible Wakonda. The symbol belonging to a village (gens) is always referred to metaphorically in the name by which the village (gens) is known, and, the symbol is also treated in the same manner in the personal names ceremonially given to every child born within the village (gens). The symbol may be an animal, as, the buffalo, or a force, as the wind, and the people are spoken of by the names of the symbol of their village, as, the buffalo people, or the wind people. There are certain articles that are regarded as associated with the different symbols. The people of a village (gens) treat with marked respect and never taste or touch such articles as are supposed to be associated with their sacred symbol.

Those villages (gentes), whose symbols are of some form or force that has its abode in the sky, have their unchangeable place in the sky section of the tribe, and those having symbols that pertain to either the land or water, have their fixed place in the earth section. During the time when tribal rites are performed, the tribe is oriented, that the people may face the ever recurring day, a symbol of life. These rites may be grouped into three classes: Those which are an appeal for the securing of food, to this class belong those rites that relate to the maize and to hunting. Those that pertain to unity and peace; to this class belong the ceremonial giving of a tribal name, the Wa-wan ceremony and certain social customs. Those which relate to war, the defense of the tribe, both as to its food supply and the life of the people. The prayer for long life, that occurs under various forms throughout the rites is understood as an epitome of these essentials to individual and to tribal life.

The Omaha distinguishes tribal rites from other ceremonies by applying to the former the term Wé-wa-çpe. The word is compound; we, signifies an instrument, a means by which something is done or brought to pass; wa-çpe, means orderly conduct, thoughtful composure. The word, according to its context can mean, religion, law, or any similar institution. As here used it signifies a means to bring the people into order, into throughtful composure. This term applied to tribal rites, bears testimony to a discriminating observation of the social value of religious observances, not only as a power to hold the people together by the bond of a common belief, but, as a means to augment the importance of self control and, of submission to authority. Rites designated as we-wé-wa-çpe, were believed to open a way between the people and the mysterious, unseen Wakonda, and any careless or irreverent act toward them, subjected the offender to supernatural punishment.

These rites are composed of dramatic acts, the recitations of rituals and the singing of ritualistic songs. In these are embodied the myths, and allegories in which the genesis of man and his relation to Nature are set forth. In the stories, symbols and metaphors are freely used, often in a highly imaginative manner and not infrequently touched with poetic feeling. By these means, the Indian's mind sought to bridge the gulf he recognized as stretching between him and the forms and forces of Nature that had so direct and yet so subtle a relation to his existence. These myths, allegories and metaphors from a nimbus about these rites that both illumines and yet makes elusive their meaning.

The Omaha, on his entrance into life is met by one of the tribal rites. He is introduced to the cosmos by the priest, standing outside the tent there, raising his right hand to the heavens, palm outward, he intones in a loud voice the following ritual hymn:

Ho! Ye Sun, Moon, Stars, all ye that move in the heavens;
I bid ye hear me!
Into your midst has come a new life!
Consent ye, I implore!
Make its path smooth, that it may reach the brow of the first hill.

The Winds, Clouds, Rain, Mist, that move in the air;
The Hills, Valleys, Rivers, Lakes, Trees, Grasses of the earth;
The Birds of the air, the Animals of the forest, the Insects that creep among the grasses and burrow in the ground are addressed in the same manner. Finally, he cries:

Ho! All ye of the heavens, all ye of the earth,
I bid ye hear me!
Into your midst has come a new life!
Consent ye, consent ye all, I implore!
Make its path smooth, then shall it travel beyond the four hills.

Infancy, Youth, Maturity, Old Age, are the four hills across which lies the rugged pathway of life.

In the social life of the Indians many little dramatic acts occur significant of beliefs, that are difficult for a stranger to understand correctly. For example: A relative comes to the home of an infant and presents it with a tiny pair of moccasins with a hole cut in each sole. The Indian mother understands the tender wish conveyed by the act. The baby is thus recognized as an Omaha child, for the mocassins anticipate the ceremony in which the "new life" is proclaimed a member of the tribe. The holes are a sign of usage, they express the giver's prayer for long life to the child. A person might enter the tent, see the tiny moccasins with the holes and exclaim: "What a long way the little one has traveled!" This too would be a prayer for long life to the child. If an unseen messenger from the spirit world should approach the infant to bid it come with him, the child would be able to say, "No, I can't go with you, look, my moccasins are worn out!" And so, the baby would not be taken away from its mother.

Both garments and the manner of wearing them ceremonially are by the Indians invested with symbolic meanings. For instance: The Robe is significant of a man's duties or purposes according to the manner in which it is worn or adjusted about his person. The position of the eagle feather on a man's scalp-lock indicates the class of act which brought to the man the right to this war honor. Other regalia made up of different articles, each one of which has its special significance, present to the Indian warrior a picture, as of the battlefield where he fought, defending his tribe, and won his honors. None of the articles employed to represent war honors or a special part taken by a man in any of the tribal rites are allowed to be used as mere adornments. A war honor can not be worn by a man until he has won the right to wear it, by the performance of a valorous act, that has been publicly recounted, approved by witnesses, in the presence of the tribe, at which time the honor appropriate to his act is accorded him, and he is authorized to wear the insignia belonging to the grade of his act.

Moccasins have a significance. Formerly each tribe had its own style of moccasin, so that a person's tribe would be indicated by the kind of moccasin he wore.

In the ceremony that marks the birth of the "new life" into the tribal organization, the dual forces are present, the masculine sky and the feminine earth; the former, represented by the "Four Winds" invoked to "come hither" in the opening ritual song; and, the latter, by the stone placed in the center of the ceremonial tent. The time when this tribal rite took place was in the spring, "when the grass was up and the meadow lark singing." The child was about four years old and must be able to go about alone and unassisted. A tent was set up and made sacred, therein the priest awaited the children brought thither by their mothers, each child carrying a new pair of moccasins. As the mother approached the tent with her child, she addressed the priest, saying: "Venerable man, I desire my child to wear moccasins!" and the little one, carrying its moccasins, entered the tent alone. According to the Omaha rite and that of some of the cognates, the priest, after summoning the "Four Winds" lifted the child upon the stone, where it stood in its bare feet facing the east, then the priest lifted it and placed it on the stone facing the south, again he lifted it and on the stone it stood facing the west, lifting it again, its feet rested on the stone as it faced the north, lastly, the priest lifted the child and it stood on the stone with its face to the east. The priest sang the following ritual song. A free translation is given.

Turned by the Winds, goes the one I send yonder,
Yonder he goes who is whirled by the Winds,
Goes where the four hills of life and the Four Winds are standing,
There into the midst of the Winds, do I send him,
Into the midst of the Winds, standing there.

The priest then puts upon the child's feet the new moccasins, makes it take four steps, and says: "Go forth on the path of life!" A personal tribal name was now given the child, one that belonged to its father's village (gens) and referred to the second symbol of its rite. This name was then proclaimed by the priest to the "Hills, Trees, Grasses, and all living creatures great and small!" in the hearing of the assembled members of the tribe.

In connection with the part symbolically taken by the Winds in this ceremony, it is interesting to note, that it was the duty of the "Wind people" to put moccasins on the feet of the dead, that they might enter the spirit land and there be recognized and able to rejoin their kindred.

* Proceedings of the National Academy of Sciences.

After a boy had ceremonially received his tribal name, on his return home, his father cut the child's hair in an established manner which was meant to typify the sacred symbol of his village. This manner of cutting a boy's hair was kept up until the child was about seven years old. The queerly cropped heads of the boys fixed in the minds of the children the symbols belonging to the different villages (gentes).

The symbolism attached to garments and the manner of wearing them, which has already been mentioned, runs extensively through the myths, allegories and metaphors, and figures that appear in the tribal rites.

A detailed presentation of the subject of this paper is impossible within the accorded limits, but from what has been given, glimpses have been obtained of the line the Indian has pursued in his endeavor to express his view of Nature and of the relation he believed to exist between its various forms and forces and himself.

In the tribal rites can be traced the gropings of the Indians' mind to find that power, greater than man, which was the source of visible Nature; to discover a way for man to approach that power so that he could receive help from it; also to search for the meaning of the activities that were everywhere apparent. The religious and social ideas developed through this search, extending through generations, as the rituals give evidence both directly and indirectly, were gradually evolved and formulated in the tribal rites, wherein was set forth, with unmistakable clearness, to the people, the importance of the perpetuation of human life upon the earth, and, of the recognition, that the life-giving power of Wakonda is ever present in all those things that surround man.

Thermal Insulation*

High Temperature Equipment for Industrial Purposes

By P. A. Boeck

THE thermal insulation of high-temperature equipment for industrial purposes is a subject that has not received from engineers and designers the attention its importance deserves. This may be attributed to a number of causes: In the first place, heat flow is a rather difficult factor to measure under the working conditions of an industrial furnace, and until the comparatively recent introduction into certain operations of the heat balance sheet, with a systematic attempt to account for the discrepancies in the totals, the various causes of heat losses and the reasons for their existence were not brought to light. Moreover, such rapid advancement and radical changes in the design of equipment, especially in metallurgical lines, have occurred that practice has apparently outdistanced the theory of design. In the modern tendency toward greatly increased size of units, effort has seemingly been made to utilize the heat of fuel gases without proper attention having been paid to conserving heat energy and confining it strictly to the points of maximum activity.

The systematic study of the thermal properties of structural materials, which is being carried out by various Government bureaus and also by a number of technical societies, is forming the basis for more intelligent and consistent work in the economically important subject of prevention of fuel waste.

It is not necessary in this practical and utilitarian age to enlarge upon the need of prevention of heat losses, but attention may advantageously be called to the other benefits derived simultaneously with the saving in fuel and the increase in thermal capacity of furnaces when properly insulated.

In most industrial furnaces—which are here spoken of in the broadest sense, indicating general high temperature equipment for any purpose and heated in any manner—the operations are generally carried on through a temperature range which has been found by practice to give the most effective results. If, in preventing the heat being dissipated from the outside of the furnace, the temperature throughout the furnace is made more uniform, the zone of reaction is manifestly greatly increased without additional fuel consumption. Furthermore, overheating at the source of heat, in the effort to bring as much of the furnace as possible into the zone of reaction, is materially reduced by preventing the loss of heat through the furnace walls. This has the ultimate effect of lowering the temperature at the source of heat and greatly increasing the life of the refractories—usually an important factor in high-temperature work. It is evident, too, that in furnaces which are surrounded by metallic casings or other equipment susceptible to the action of high temperatures, the deterioration and damage caused by overheating may readily amount to many times the cost of installing the proper protecting insulation. The humanitarian will also see the advantages gained by the protection of workmen from the unhealthy and unsanitary conditions brought about by being compelled to labor under overheated conditions.

The importance of thermal efficiency of all manner of high-temperature equipment is now being more generally recognized and is receiving much attention.

Without going into a detailed consideration of the general laws governing the flow of heat, it would be well to call attention briefly to the following facts regarding heat flow, which will be illustrated by reference to the steam boiler as a well-known example:

The United States Bureau of Mines has treated[1] this subject in a remarkably clear and concise manner in Bulletin No. 18, to which reference should be had by those desiring to refresh their memories as to the principles of heat radiation, convection, and conduction.

The energy in the form of heat which eventually finds its way into the water in a boiler, for example, is, of course, subsequently available in other forms. That portion, however, which is transferred to the walls of the furnace setting by any of the three methods mentioned, is conducted through the setting, if means are not provided to prevent, and is lost by radiation or convection from the outer surface of the setting. It is the heat lost in this manner and methods for its prevention that will be especially considered in this discussion.

The rate of transfer of heat under various conditions, by both conduction and radiation, shows the relative importance of these two methods in influencing heat losses. The amount of heat conducted through a unit area from one part of the body to another is proportional to the difference in temperature of the two parts; directly proportional to the thermal conductivity of the body through which the heat passes and inversely proportional to the distance between the two parts of the body. In other words, the conduction of heat through a solid body from one plane to another is a direct function of the conductivity of the body and the difference in temperature of the two planes and an indirect function of their distance apart.[2] This is identical with Ohm's law for transfer of electrical energy.

The heat transferred from one body to another by radiation is proportional to the difference of the fourth powers of the absolute temperatures of the two bodies. While this is strictly true only of the ideal "black bodies," the variation is so small that for all practical purposes this relation holds good in ordinary procedure.[3]

This relation indicates the reason why, in low-temperature work, such as refrigeration, etc., a hollow wall space is an effective insulator, whereas, in high temperature operations, the loss of heat by radiation through a hollow wall space is so great that its insulating effect is less than if this wall space were filled with material of rather high thermal conductivity. This has been brought out by Ray and Kreisinger, who again demonstrate that the hollow wall space type of wall construction is much less effective as a means for preventing the loss of heat than a solid wall of any ordinary construction material of equal thickness. This is especially true if the air space in the hollow wall is near the furnace side and becomes highly heated. This is entirely contradictory to the general belief that, since air is a poor conductor of heat, air spaces built into the walls of a furnace will greatly reduce heat loss by radiation. While the heat does travel very slowly through the air by conduction, it leaps over the air space readily, by radiation, because the quantity of heat which passes across the hollow space is a function of the fourth power of the absolute temperatures of the surfaces inclosing it, which loss is enormously increased by rise in temperature.

In general, in high temperature furnace construction, there are two separate and distinct factors which must be considered to produce an effective wall. The first of these is to provide a material having the ability to resist the action of high temperatures, sufficient mechanical strength, and, possibly, the property of resisting corrosive slags, gases, etc., without spalling or being eroded. Secondly, to prevent the excessive loss of heat due to conduction from the interior of the furnace to the outside, where it is lost. It is rare that a good refractory material is a good insulator; usually it is necessary to augment or back up the refractory with some material having a much lower heat-conducting capacity. As a general rule, light porous substances are good thermal insulators; and, in a great majority of cases, this depends upon their entrapped voids, their apparent density being an excellent criterion of their conducting ability.

The requirements of the insulating backing for the more refractory lining are rather severe; an ideal insulator would have the following properties: It should be extremely high in insulating value, and sufficiently refractory so that no fusing or excessive shrinkage would take place in that portion which is in direct contact with the highly heated refractory wall. It should not be decomposed or change greatly in volume at that temperature, and it should, furthermore, be of light weight, unaffected by moisture, of convenient form, readily applied by unskilled labor, and low in cost. It should be of such composition as not to react upon or attack either the refractory material or the metal shell of the container, even in the presence of moisture; i. e., it should contain no free acid radicals, and should not be broken or caused to settle by vibration or heat. It should not have high expansion and it should be sufficiently elastic to take up strains between the lining and the shell produced by temperature changes. While this is a rather formidable array of requirements, there are products upon the market which fulfill practically all of them.

Such materials as are being commonly applied to steam temperature insulation, of which magnesia and asbestos are best known, are, of course, eliminated from consideration in the great majority of cases mentioned here. The lack of more extended practice in high temperature insulation must be attributed to the fact that effective high temperature nonconductors have not been generally available.

When the kind of refractory material that is best suited to the furnace has been determined, the next most important item is the thickness of the walls and the nature of the insulating material most suitable, and it is necessary to determine the degree of insulation which will produce the most effective results. Hering has pointed out that, in order to effect a perfect insulation, the furnace should be surrounded with an insulating material that would maintain the same temperature at any point as that of any adjacent point of the lining; in other words, that there should be a uniform amount of heat loss throughout the lining.[4]

In attempting to obtain perfect insulation, it is entirely possible to over-insulate, causing serious damage to the refractories in the high temperature zones of the furnace. To maintain the inner walls, it may be necessary to permit a considerable flow of heat through the wall, with a corresponding decrease in the temperature of the refractories at the heated point, in order to prevent their destruction. It would be manifestly impracticable to insulate the roof of an electric steel furnace or open-hearth furnace, for instance, with a heavy layer of insulating material, because the cost of the refractory lining which would be destroyed would be considerably greater than the cost of the heat which would otherwise be lost.[5]

In electric furnace practice, where extremely high temperatures are encountered and where effective insulation is necessary because of the relatively high cost of current, the question of insulation, or rather over-insulation, has been given more attention than in other lines. F. T. Snyder[6] has presented a detailed study of the nature and amount of insulation which is permissible under various conditions and presents many valuable data which might with advantage be applied to other industries.

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* *Bulletin of American Institute of Mining Engineers.*

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[3] Gurney, Harold P.: Heat Radiation, *Journal of Industrial and Engineering Chemistry*, vol. iii, No. 11, p. 807 (Nov., 1911).

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Coal Gas Residuals*

Valuable By-Products and Methods By Which They Are Saved

By Fred H. Wagner

A HUNDRED years of development have passed since Murdoch lighted the city of London with coal gas, and these years have placed gas lighting in the forefront of industrial progress, while the history of these years plainly shows how the proper utilization of by-products can revolutionize the magnitude of an industry. The early years of coal carbonization could depend upon no, or but very little, assistance from by-produce sales in the matter of cheapening the cost production, and not until the aid of modern chemistry was called in did the production of residuals make any appreciable change in this condition.

The recovery of residuals is a very important conservation of resources, and it forms one of the principal means of revenue to the coal gas producer, the sale of these residuals reducing the cost of gas production in a degree corresponding to the efficiency of the recovery methods adopted and the market value of the product.

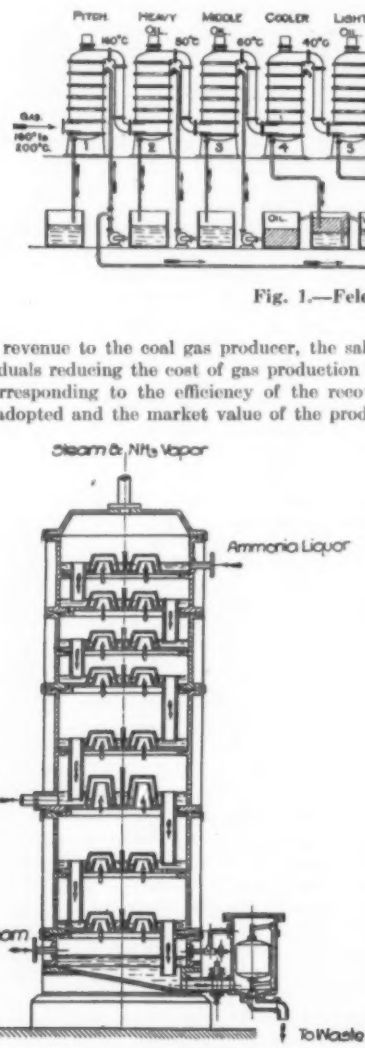

Fig. 3.—Continuous ammonia still.

The principal residuals recovered to-day are tar, naphthalene, cyanogen compounds, ammonia, and, in the case of coke oven gas, also benzol by a direct recovery method, and they will be treated in this consecutive order in the following pages; the recovery of benzol is confined almost entirely to the coke-oven plant, where a direct method of recovery is adopted, and to the tar distiller, benzol being one of the most valuable of tar constituents. While the recovery of naphthalene cannot exactly be termed one of profit in a pecuniary sense at present, the removal of a certain portion from the gas is of distinct advantage, and the methods adopted for its removal will, therefore, be given.

The gas produced during the carbonization of coal is a mixture of fixed gases, vapors of various kinds, and, at times, also globules of liquids, which are held in suspension, and are thus carried forward by the gas; these gases and vapors also carry forward some solid carbon in the shape of dust.

The principal fixed gases are hydrogen, H_2; methane, CH_4, also known as "marsh" gas; ethane, C_2H_6; propane, C_3H_8; butane, C_4H_{10}; ethylene, C_2H_4; small amounts of butylene, C_4H_8; propylene, C_3H_6; acetylene, C_2H_2; carbon dioxide, CO_2; carbon monoxide, CO; hydrogen sulphide, H_2S; nitrogen, N; oxygen, O, and ammonia, NH_3; while the principal vapors in the mixture are benzol, C_6H_6; toluol, $C_6H_5CH_3$; xylol, C_6H_4 (CH_3) carbon disulphide, CS_2, and aqueous vapors. These latter vapors all pertain to substances which become liquid at ordinary temperatures, but the vapors of napthalene, $C_{10}H_8$, phenols, etc., pertain to substances which become solid at ordinary temperatures, and must, therefore, be subjected to a special treatment.

As will be seen later, some of these constituents are of inestimable value to the coal-gas producer, and consequently the treatment of the gas after it is produced in the carbonizing plant is of great importance; this treatment should not only consist of a method of cooling the gas, and thus condensing and precipitating the vapors as a fluid, but the method of treatment should be such as to retain in the gas those valuable illuminating constituents which may be lost to a greater or lesser extent in the usual condensing plant.

The Feld system of condensation and purification of coal gas, which embraces successive cooling with a fractionation of the products, appears most attractive from the standpoint of efficiency and simplicity.

The usual condensing system in coal-gas practice embraces the use of a primary condenser, exhauster, tar extractor, secondary condenser, and ammonia washer; the tar, together with quite an amount of illuminants, being thus removed in a greater measure by cooling, while in the Feld system, the gas is not cooled below a point where any volatile hydrocarbons are precipitated or absorbed by the effluent, the tar being fractionated in three washers into pitch, heavy oils, and middle or light oils, and the gas is treated for cyanogen compounds, combined hydrogen sulphide and ammonia, naphthalene, and finally benzol, the entire process being carried out in Feld vertical centrifugal washers, as shown in Fig. 1.

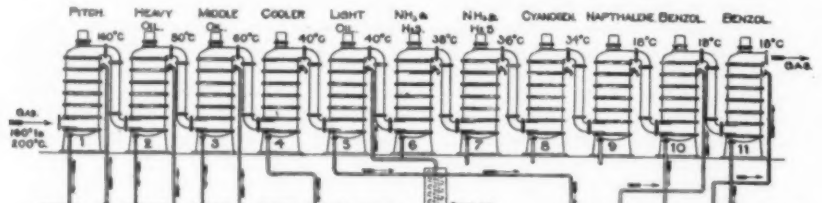

Fig. 1.—Feld condensing apparatus.

As will be seen from Fig. 1, the entire condensing plant consists of eleven washers, the first or pitch washer operating at a temperature of from 320 degrees to 392 deg. Fahr., the gas being kept at this temperature from the hydraulic main by insulating both the main and the pipe connections, or by the application of external heat, heavy oils from washer 2 being pumped into washer 1 where they are used as the active pitch extracting medium.

Washer 2 removes the heavy oils, and it is operated at a temperature of from 320 degrees to 176 deg. Fahr., all operating temperatures being determined from the actual dew-point of the gas for the constituent to be removed, the extracting medium being the middle oils from washer 3.

Washer 3 removes the middle oils, due to contact between the gas and the oils separated by cooling in washer 4, this cooling being effected by bringing the gas into intimate contact with water, the effluent from washer 4 being run into a separating tank where the oil is separated from the water by specific gravity.

The light oils are removed in washer 5 where the gases are washed by means of heavy oils which are previously cooled in a special cooler, these oils from 5 being run into a reservoir from whence they are pumped into the first benzol washer.

The washers for ammonia and hydrogen sulphide operate under a temperature of from 104 degrees to 97 deg. Fahr., the hydrogen sulphide being combined with the ammonia in these washers with the consequent formation of ammonium sulphate, while the cyanogen washer operates at about 97 degrees to 93 deg. Fahr.

The naphthalene is removed in washer 9 at a temperature of about 65 deg. Fahr., while washers 10 and 11 serve to extract the benzol and its homologues, the partially saturated oil coming from washer 10 being pumped into washer 11.

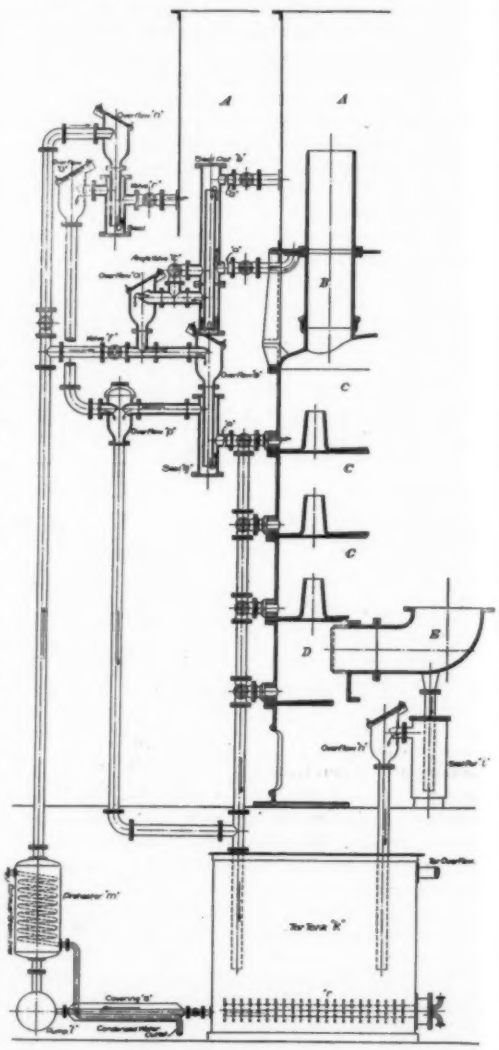

Fig. 2.—Feld hot tar washer.

TAR.

Tar is a thick, dark brown, viscid, oily liquid, produced during the dry distillation of coal; its chemical nature is very complex, and it contains a large number of compounds. The crude gas leaving the retorts is a mixture of permanent gases, but this mixture carries with it quite a number of hydrocarbons and other vapors, and as the illuminating, as well as the calorific, quality of coal gas is, in a great measure, dependent upon its hydrocarbon constituents, it is of prime importance to treat the gas so as to retain as many of these hydrocarbons as is possible. A reduction in temperature, however, soon reduces the hydrocarbons of greater density to liquid form, and this liquid is usually termed "tar." In spite of the fact that the gas temperature at the hydraulic main is perhaps never lower than 145 deg. Fahr., large quantities of tar are deposited at this point, and it is, therefore, almost impossible to retain the hydrocarbons of this class in the gas with the usual method of condensation.

Both the nature of the coal used and the temperature of carbonization exercise a great influence upon the quantity, as well as upon the quality of the tar produced, thus both quantity and quality regulating the amount of revenue received, and in this manner, governing, to a great extent, the final cost of gas production.

In the usual systems as applied at present, the removal, or the precipitation of tar, is accomplished by condensation or cooling; quite an amount of condensation occurs between the retort and the hydraulic main, a further amount of tar being deposited in the hydraulic main proper, after which the gas is conducted to the condensers where gradual cooling further reduces the tar content. After leaving the condensers, the gas still contains quite a number of tar globules in suspension, it being possible

* Paper read before the American Gas Institute. Copyright, 1914, by American Gas Institute.

to remove only these last traces of tar by means of friction.

In the Feld system, a different method is employed as the heat contained in the gas is utilized by a system of fractional coolings to separate, or wash out of the gas, tar in several of its principal constituents. This treatment may also be varied in such manner as to prevent the formation of tar as much as possible by maintaining the heat of the gas coming from the retorts at a temperature above the dew-point of the gas for the constituents of high boiling points. This may be done by covering the connections from the retorts to the first washer with insulating material, or by applying heat to the exterior of the pipes. The gas thus protected is led to the washers where it is subjected to fractional cooling and successive washings at successively lower temperatures, so that the various tar constituents are separated from each other by employing the temperature of the gas itself, and without the necessity of employing extraneous heat after previous cooling.

A Feld washer especially arranged for hot tar washing is shown in Fig. 2, and in order that aqueous condensation may be avoided in the washer by reducing the temperature of the gas to the dew-point for water, the washing tar should be heated to from 40 degrees to 60 deg. Fahr. above the temperature of the gas at the inlet to the washer, this hot tar being the active tar extracting medium.

In Fig. 2, which shows a portion of a Feld washer with superimposed Pelouze condenser, *A* is a Pelouze condenser; *B*, gas port in washing chamber; *C*, upper washing chamber; *D*, lower washing chamber; *E*, gas inlet; *k*, basin, or tank containing wash tar; *r*, radiator, or steam coil; *l*, rotary tar pump; *m*, preheater for wash tar; *s*, insulated connection from tank (*k*) to pump (*l*).

In order to keep the wash tar at the desired temperature, the steam pipe from *m* is beneath pipe *s*.

The hot wash tar is pumped from tank *k* through the insulated connection *s* and preheater *m* to the Pelouze condenser *A* through the overflow pot *n*; any surplus tar overflows at *O* and *p* and returns to tank *k*.

The tar overflows from the Pelouze through *b* and *d*, *e* and *g*, into the upper chamber *C* of the washer, where it is picked up by the washing cones within the chamber and spread out over the entire gas space, the depth of the spray being from 8 inches to 14 inches, depending upon the size of the washer. The gas is thus brought into intimate contact with the hot wash tar, and is subjected to a thorough washing, the wash tar as well as the tar expelled from the gas, overflowing through the gas port to the next lower washing chamber; here the wash tar is again placed in circulation by the cones in this chamber, and the total combined tar finally leaves the washer through the pot *i* attached to the gas inlet connection, and by means of overflow *h* enters tank *k*, all surplus tar from this tank flowing off to the tar storage.

In order that the maximum results may be secured, the wash tar should be constantly circulated through the washer, but it is not always necessary to circulate it through the Pelouze condenser, this omission being dependent upon the condition of the tar in the gas. The amount of hot tar to be circulated through the washer may vary from 0.5 to 2.5 gallons per 1,000 cubic meters of gas per hour; larger volumes of gas require proportionally less circulating tar than do smaller volumes, but the amount of washing tar circulated must be so regulated as to prevent the temperature of the gas reducing the temperature of the wash tar.

The circulating wash tar should be pumped through the preheater *m* before it enters the washer, this preheater being supplied with a steam coil, and in some cases it may be necessary to insulate the tank containing the wash tar, depending upon its location, and even the washer proper with some insulating material, in order to increase the efficiency, as many of these washers are set up in the open in Europe, being thus exposed to the weather.

The tank containing the wash tar is also provided with a steam coil, or radiator, made in one piece in order to prevent leaks and thus mix water with the tar. Care must be exercised in operation to the extent of preventing the deposit of thick tar in the Pelouze condenser, and if the washer should be stopped for any reason, it must be emptied of tar at once in order to avoid cooling the tar and thus clogging up the passages.

Table I gives the results secured in washing with hot tar, the washer being supplied with a Pelouze condenser in the one instance, but not in the other.

TABLE I.—FELD HOT TAR WASHING.

Gas temperature at Inlet to Washer.	Tar Content in Grains per Cubic Feet.		Grains Removed.	Efficiency, per cent.	Gas passed per 24 Hours, Cubic Feet.
	Inlet	Outlet			
Washer Without Pelouze Condenser.					
131 deg. Fahr..	11.512	0.2930	11.219	97.46	2,463,000
127 deg. Fahr..	10.386	0.2160	10.170	97.92	2,453,832
129 deg. Fahr..	10.818	0.2930	10.525	97.29	2,341,800
129 deg. Fahr..	13.518	0.4170	13.101	96.92	2,397,000
126 deg. Fahr..	9.907	0.5250	9.382	94.70	2,400,000
Washer With Pelouze Condenser.					
140 deg. Fahr..	10.050	0.0436	10.0064	99.56	2,600,000
194 deg. Fahr..	13.100	0.0872	13.0128	99.34	2,600,000

The Feld process of tar washing was installed in a works in Bohemia in 1907, and the tar was fractionated into pitch, heavy oil, and light oil, with the result that the tar produced by the old method of condensation sold for $5 per ton, while with the use of the Feld system producing the oils direct from the gas, the equivalent of this ton of tar sold for $16.

NAPATHALENE.

Naphthalene ($C_{10}H_8$) is a hydrocarbon and has a melting point of 174 deg. Fahr., a boiling point of 424 deg. Fahr., and it sublimes at lower temperatures. The deposition of naphthalene in a solid state in the mains or apparatus causes many operating difficulties, as it decreases the cross-sectional area of the gas conduits and thus produces quite some back pressure on the work.

The presence of naphthalene in the gas is probably due to the high heats employed in present-day carbonization, and it is presumed that these high heats cause a partial distillation of the tar with the consequent formation of naphthalene.

The greater portion of the naphthalene produced especially with high distillation or carbonization temperatures, goes over into the tar, the gas containing only a portion of the naphthalene vapor, its maximum content being dependent upon saturation at various temperatures, but outside of the temperature of carbonization the amount of naphthalene present at any time in the gas is also due largely to the character of the coal used, and also upon the time of contact between the gas and the hot coke and the hot retort walls.

The amount of naphthalene required to saturate a gas varies according to different investigators, none of them agreeing with each other.

In order to avoid stoppages in the pipe connections due to sublimation, it would be necessary to cool the gas as nearly as possible to a temperature corresponding to that of the gas in the buried mains, but as it is almost impossible to do this during cold weather, it becomes necessary to remove the naphthalene from the gas by means of a suitable extracting medium.

The best solvents for this purpose are anthracene oil, creosote oil, and water gas tar; the tar from vertical retorts has also been used for this purpose, but this tar must first be subjected to complete cooling.

If all of the naphthalene should be removed from the gas, the latter would suffer considerably in candlepower, and no more should be expelled than what would produce sublimation with consequent stoppages.

Under ordinary conditions, 100 grains of anthracine oil will absorb from 10 to 25 grains of naphthalene, according to temperature, but before using this oil from 3 to 4 per cent of benzol should be added, this addition leading to greater extraction efficiency, this efficiency being further increased by thoroughly and slowly cooling the gas, as the absorption is most complete at a temperature of from 60 degrees to 70 deg. Fahr.

One per cent of creosote oil will, under ordinary conditions, absorb 1 per cent of naphthalene, by weight, but this absorption is dependent upon the amount of phenols present.

Water gas tar will absorb from 18 to 20 per cent of its own weight in naphthalene, this absorption efficiency

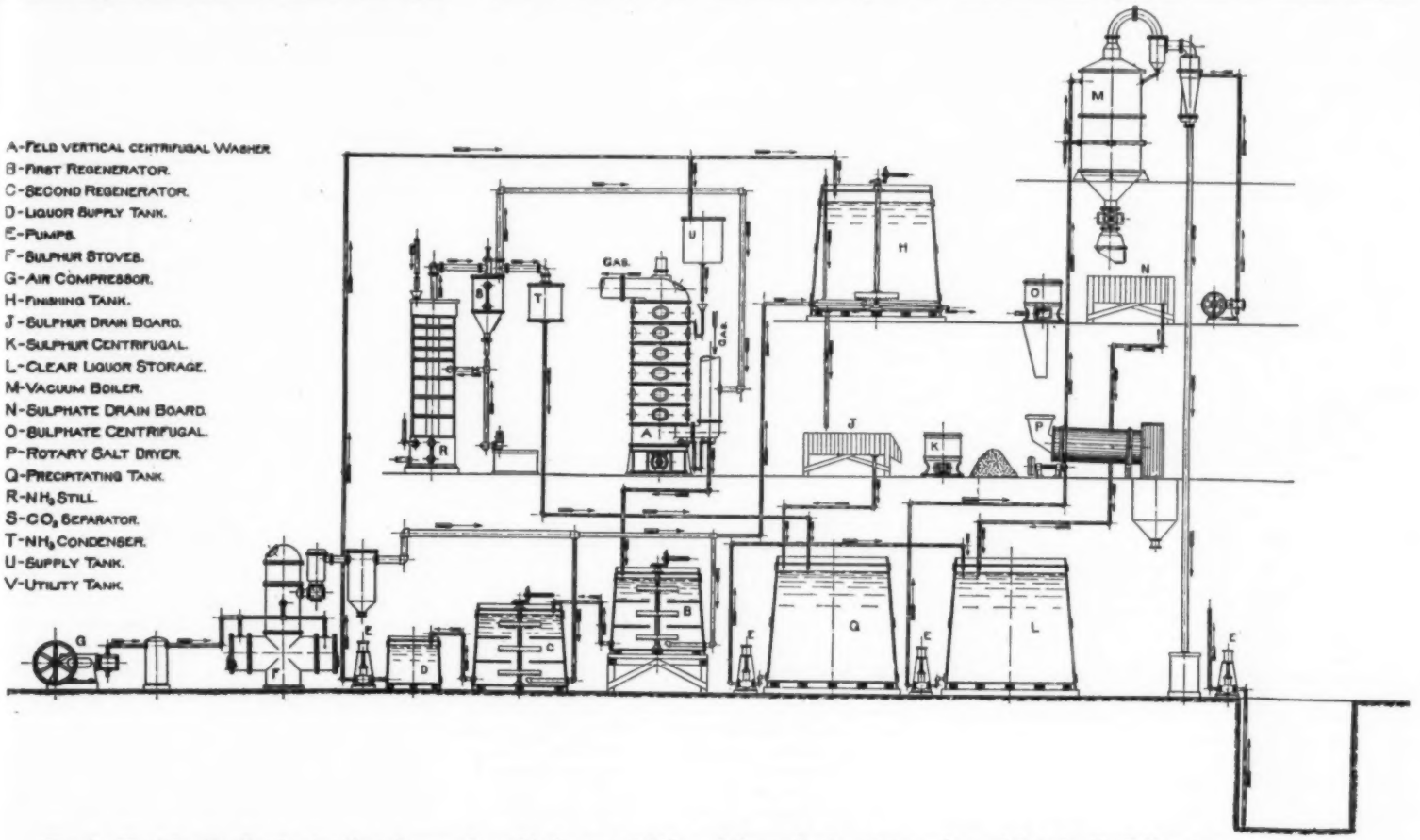

Fig. 4.—Plant for the direct extraction of ammonia and hydrogen sulphide, and the production of ammonium sulphate by the Feld process.

also being dependent upon the amount of phenols present.

If water gas tar, or if water gas oil, is used as the absorbing medium, it can be run back to storage bearing its naphthalene burden, as the latter is not detrimental to the further use of the tar or oil, but if anthracene or creosote oil is used this oil can be regenerated for further use by being distilled and condensed, the naphthalene crystals being thus caused to crystallize out.

An attempt has lately been made to use naphthalene as fuel in internal combustion engines, and some success has been met with in this direction; the present drawback seems to be the fact that it is necessary to start the engine with gas or some liquid fuel, and to so operate it until the heat generated by the engine is sufficient to melt the naphthalene, after which the latter is fed to the engine, vaporized, and exploded. Complete success in this direction would soon open up another source of revenue to the producer of coal gas.

It may be interesting to state that a locomotive operating on naphthalene has recently been constructed in France; this locomotive is provided with four cylinders, each two cast en-bloc, 5.5-inch bore by 8-inch stroke, 70 horse-power being developed at 950 revolutions per minute. This machine is provided with two carburetors, one used on starting with spirit, and the other for the naphthalene. The carburetor used in connection with the naphthalene is cast en-bloc with the reservoir in which the naphthalene is melted, double walls for the circulation of cooling water being provided, the temperature of this water being maintained at 212 deg. Fahr., thus maintaining a constant melting temperature.

CYANOGEN.

Cyanogen (C_2N_2) is a gas composed of carbon and nitrogen, and it is probably produced during the period of carbonization in the form of hydrocyanic acid by the decomposition of some of the ammonia due to contact with the hot coke in the retort, as per the equation,

$$C + NH_3 = HCN + H_2,$$

and the amount of cyanogen produced by the carbonization of any particular coal bears a certain relation to the amount of nitrogen contained in the coal.

The removal of cyanogen from coal gas is of decided advantage for two reasons, (1) owing to its corrosive effect on works apparatus; (2) because it is a valuable by-product under certain conditions; also if cyanogen is permitted to pass on into the purifiers, it will be found to enter into combination with the iron in the purifying material, thus rendering a certain portion of this iron inactive for hydrogen sulphide extraction; on the other hand, the sale of spent oxide containing a high percentage of cyanogen is more remunerative than if it contained only sulphur, as this oxide is often purchased on the basis of its "prussian blue" contents only, "prussian blue" being the name applied to this cyanogen combination.

The revenue to be derived from the extraction of cyanogen from coal gas is dependent upon the amount of coal carbonized and upon the market price of the product, the latter fluctuating constantly; it is certainly not a remunerative proposition for works carbonizing less than 250 tons of coal per day, as the same labor expended on a plant of this size can readily handle the proposition in one of double the capacity.

The estimated revenue in a plant carbonizing 250 tons of coal at the works, and 750 tons at another, the sludge from both being worked up in one plant, after deducting operating expenses and 6 per cent interest and 6 per cent for depreciation, amounts to $27,935 per year, and this, without the additional revenue, to be derived by the production of ammonium sulphate from the cyanogen press liquor, this liquor being sold on the basis of concentrated ammonia. Besides this revenue, the extraction of cyanogen in this case shows an aid of 22 per cent in the action of the purifiers, or the life of the oxide is increased by 22 per cent.

The two systems of cyanogen recovery which have met with the most pronounced success, is that of Bueb, and the one devised by Feld, the former making an insoluble ferro-cyanide coke, and the latter a soluble cyanide sludge.

For a description covering the extraction of cyanogen by the Bueb process, attention is called to the paper read by Mr. M. E. Mueller during the 1910 meeting of the Institute, and which appeared in the *Proceedings* of that year.

The Feld process of cyanogen extraction differs from that of Bueb in that it is applied after the ammonia has been removed from the gas, this alkali being replaced with milk of lime in the copperas washing medium. The combined solution of lime and copperas is run into the Feld vertical washer, the resultant sludge coming from the bottom of the washer being boiled and then filter-pressed, the product coming from the filter press being calcium ferro-cyanide.

The product coming from either the Bueb or Feld plant, is usually worked up into potassium ferro-cyanide, and in this case the working up of the sludge produced by the Bueb system requires additional apparatus for the removal and concentration of the ammonia carried in the sludge, while the working up of Feld sludge obviates the necessity of this ammonia apparatus, as the Feld system embraces the removal of cyanogen from the gas after the ammonia has been extracted.

AMMONIA.

Ammonia is a product derived from the destructive distillation of coal, and it results from the union of nitrogen with hydrogen, or $N + H_3 = NH_3$; besides being an important source of revenue, the removal of ammonia from gas is necessary on account of its destructive influence on the brass and copper work of meters and gas fittings; when burned with gas it gives off noxious fumes of oxides of nitrogen.

The usual method employed for the removal of ammonia depends upon its solubility in water, and at ordinary temperatures water can absorb about 708 times its volume of pure ammonia gas, the absorption increasing with a decrease in water temperature, or

One volume of water at	32° F.	will absorb	1050	volumes of	NH_3
" "	50° F.	"	813	"	"
" "	59° F.	"	727	"	"
" "	68° F.	"	654	"	"
" "	77° F.	"	586	"	"
" "	183° F.	"	180	"	"

providing the pressure of the ammonia gas is equal to that of the atmosphere, and if the gas carries no tar burden.

The usual gas works method of operation, as practiced in America, removes the ammonia by condensation and washing, the first portion of the ammonia being removed in the hydraulic main due to the condensation of water vapors, which thus absorb ammonia. Cooling the gas in the condensers also causes the deposition of quite an amount of water which in turn absorbs more ammonia, the final ammonia being removed in the scrubbers or mechanical washers, using as little wash water as is consistent with the result desired, viz.: strong liquor.

Raw ammonia liquor from the plant usually contains from 1 to 2 per cent of ammonia, and due to the cost of transportation, it would not, in most cases, be economical to sell this liquor in its diluted state; the raw liquor is, therefore, usually worked up for one of the following ammonia products: (1) Concentrated liquor; (2) aqua ammonia; (3) sulphate of ammonia; but the product to be recommended for any particular gas works must necessarily depend upon local market conditions.

Concentrated ammonia is a product in which the raw liquor has been freed of a large portion of water, and it is used for producing other ammonia products.

Aqua ammonia is a solution of ammonia in distilled water, a great deal of it, in a dilute solution, being used for cleansing purposes.

Ammonium sulphate is produced by distilling the liquor, and absorbing in sulphuric acid; by passing the gas through an acid bath, thus absorbing the ammonia, or by combining the ammonia in the gas directly with the sulphur radical, discarding sulphuric acid.

The working up of the liquor is usually effected in continuous stills, Fig. 3, operating with a supply of live steam, and as the principle of design and operation is practically the same in the usual stills on the market, only one method will be described, the other differing only in detail and not in principle.

The still usually consists of a series of superimposed sections, one mounted upon the other, constructed of cast iron, each section being provided with a steam passage in the bottom, covered with a hood or bell, and an internal overflow for liquor. These sections should be liberally provided with cleaning holes, by means of which access can be had to every part of the interior, so that the apparatus can be thoroughly cleaned without dismantling it. The liquor having been previously heated, enters at the top of the still and flows from section to section in a direction opposite to that of the steam, which enters at the bottom, passes up through the steam passages, and is caused to pass through the liquor by means of the hoods or bells.

The crude liquor is thus gradually brought to the boiling point, the free ammonia and other gases mixing with the steam in the upper portion of the apparatus. The milk of lime is introduced in small quantities into the lower or liming sections, the hoods of these sections having a somewhat deeper seal than the others, in order to permit of more efficient mixing of lime and liquor. A final boiling of the liquor in the lower sections completely liberates all of the fixed ammonia, and the stills should be so operated that the waste liquors leaving the bottom should not contain more than 0.005 per cent of ammonia.

If concentrated liquor is to be produced, the vapors coming from the still are washed in a lime washer in order to remove any carbonate of ammonia that may be formed, after which the vapors are condensed and run into storage.

The earning capacity of a concentrating plant operating in conjunction with a plant carbonizing 300 tons of coal per day, should be, with ammonia at 8 cents per pound, about $25,788 per year, or

375,000 pounds of ammonia at 8 cents		$30,000
Labor	$1,830	
Materials	1,922	
Miscellaneous	460	
Total operating cost, less interest and depreciation		4,212
Profit per year		$25,788

If the weak liquor, as produced in the works, can be sold as such, and if the ammonia in this liquor, based on the above prices of concentration, is worth 6 cents a pound, the yearly gross revenue for this ammonia should be $22,500, but from this would have to be deducted the added freight due to shipping a larger bulk, if the ammonia liquor is to be transported away from the works, as well as pumping charges. In order to make the sale of weak liquor a profitable undertaking as compared with concentrate, it would be necessary that an ammonia works, which would take the entire output of liquor, be established in very close proximity to the gas works.

If aqua ammonia is to be produced, the vapors from the still are sent into lime washers, coolers, charcoal filters, oil washers, caustic soda washers, and finally into the absorbers.

The earning capacity of an aqua plant of the same size as that quoted above, should be about $47,030 per year, or

780 tons of 26 degree Bé aqua at $102		$79,560
Labor	$3,630	
Materials	7,610	
Miscellaneous	21,290	
Total operating cost, less interest and depreciation		32,530
Profit per year		$47,030

If sulphate is to be made from the ammonia vapors, these vapors are sent into the saturators containing sulphuric acid, where the ammonia and the acid combine to form the sulphate, and the earning capacity of such a plant of the same size as those quoted above, should be about $30,809 per year, or

727 tons of sulphate at $60		$43,620
Labor	$1,830	
Material	10,221	
Miscellaneous	760	
Total operating cost, less interest and depreciation		12,811
Profit per year		$30,809

The net earnings of these three plants is based on 250 maximum working days. During the last fifteen years, the attention of investigators has been turned toward an endeavor to simplify the methods used to produce ammonium sulphate from the product due to coal distillation, and instead of treating the gas liquor itself, as in the old or in direct system just described, the endeavor has been to pass the gas directly into and through the saturator, which is a closed one in this case; this method of procedure has been termed the "direct process" and, as the name indicates, it is a reversal of the old method. Other investigators have proceeded along somewhat different lines, and while passing the gas through the closed saturator, they, at the same time, vaporize the ammonia produced by previous condensation and then pass these vapors into the saturator in conjunction with the gas, this latter development being known as the "semi-direct" process.

The Feld system is even more truly a "direct process" than any of the methods mentioned above, as saturators containing sulphuric acid are not used, and when it is remembered that the production of one ton of sulphate requires approximately one ton of acid, the importance of this advanced step can be realized, Feld combining the sulphur in the gas with the ammonia, thus producing ammonium sulphate by his polythionate process, no other oxidizing agent, except atmospheric oxygen, being required, and the latter is used only in the sulphur stove where the sulphur is burned to form sulphur dioxide, this sulphur stove thus displacing the sulphuric acid factory which has hitherto been a necessity.

The method of operation can best be understood by following the diagram, Fig. 4. The plant is started by filling the two generator tanks *B* and *C* as well as the wash liquor tank *D* with weak ammonia liquor from the works or with fresh water, this liquor or water being then pumped into the supply tank *U*, from whence it flows into the top of the washer *A*. Ammonia extraction immediately follows, and the liquor flows from the bottom of the washer as thio-sulphate, entering regenerator *B* where it is treated with sulphur dioxide coming from the sulphur stove *F*, the sulphur dioxide being forced through the liquor due to pressure produced by the compressor *G*. The overflow from generator *B* enters regenerator *C*, where a further treatment with sulphur dioxide is effected, and then enters the wash liquor tank *D*, from whence it is again pumped to the washer.

Alternately treating the liquor with sulphur dioxide and with crude gas forms polythionate in the first instance and thio-sulphate in the second, the polythionate being the active washing medium; an equivalent amount of hydrogen sulphide is removed from the gas in conjunction with the ammonia in the washer.

When the liquor has obtained a strength equivalent

to 35 or 40 per cent ammonium sulphate, a portion of this concentrated solution is pumped into the oxidation or finishing tank *H*, it being replaced in the circulating system with weak liquor from prior condensation. In the finishing tank *H* the polythionate liquor is treated with heat through the medium of a steam coil, and some sulphur dioxide, if this should be necessary; by this treatment the thio-sulphates are transformed into polythionates which are in turn decomposed into sulphate and free sulphur.

The liquor, when decomposed, is drawn off from the finishing tank onto the sulphur drain board *J*, and the free sulphur, which is in the form of hard grains, is placed in the centrifugal *K* where its moisture is expelled; this sulphur is returned to the sulphur stove *F* for the further production of sulphur dioxide.

The liquor from the drain board, *J*, as well as that from the centrifugal *K*, flows to the precipitating tank *Q*, where it is treated with some concentrated ammonia, or $(NH_4)_2S$ from the condenser *T*; this liquor is then transferred to the storage tank *L* and is pumped from there to the vacuum boiler *M*. The concentrated ammonia, or $(NH_4)_2S$, from the still and condenser is sent into the precipitating tank in order that any iron held in suspension may be thrown down, thus ensuring a clean, white salt; the amount of ammonia used for this purpose is very small, but it is all recovered in the sulphate. The liquor is evaporated in a vacuum (an open evaporator may be used if desired) in the boiler, and the salts are drawn out into the drain board *N* and from there to the centrifugal *O* and rotary dryer *P*, the salts thus produced being ready for bagging and shipping. All mother liquor from the drainboard and centrifugal returns to tank *L* and is from thence pumped back into the boiler.

The still *R* is used for the purpose of evaporating any ammonia liquor thrown down by previous condensation, these vapors being returned to the gas at the inlet to the washer, a small portion of the vapor being sent into the condenser *T* for producing the $(NH_4)_2S$ used in the precipitating tank. The use of a still is dependent upon the method of operation; if Feld's system of hot tar extraction is installed a still will not be necessary, as there will be no precipitation of ammonia under these conditions; a still is also not necessary if the production of ammonia liquor does not exceed the amount of liquor required in circulation.

This process requires but very little expert control, the usual mechanics, attending the machinery being capable of making the necessary liquor tests after some little instruction.

The Bueb process for the extraction of cyanogen produces ammonium sulphate in solution, and therefore, this process, in combination with the Feld explained above, forms a very remunerative proposition.

The income from such a combined plant in a works carbonizing 300 tons of coal per day is approximately as follows, based on 250 maximum days per year:

Cyanogen	128,500 lb. at 13.25c.	$17,025.00
Sulphate	1,349,250 lb. at 3.00c.	40,477.50
NH_3 in press cake	29,750 lb. at 7.00c.	2,082.50
Total gross earnings		$59,585.00
The operating expenses are:		
Materials		$3,695
Steam		1,663
Power		2,688
Miscellaneous		1,000
Labor		2,500
Total operating expenses		11,546.00
Net earnings per year less interest and depreciation		$48,039.00

BENZOL.

While the removal of benzol from gas is not of remunerative interest to the coal gas producer under the present antiquated standard of gas sale by candlepower, it is of special interest to the by-product coke oven operator, and as all of the preceding data applies to both of these producers, the method of removing and purifying benzol, is herewith included.

Benzol is recovered from coal gas after the tar and ammonia have been removed, and all modern systems are based on the original process as carried out by Brunck in Germany in 1887. The gas is washed in a series of washers with light oil, this oil absorbing the benzol, after which the raw product is subjected to a number of distillations, producing benzol, toluol, xylol and solvent naphtha.

The Koppers Company states that the income due to the extraction of benzol from the gas produced by the carbonization of 2,000 net tons of dry coal per day, is $138,610, or 46 per cent on the investment capital.

The Liquefaction of Carbon

And the Temperature and Conditions of the Electric Arc

CARBON is the only one of the better known elements which seems to resist all attempts of liquefaction. The solution of the problem would scientifically be most important, and it excites popular interest. For, people say, if carbon were once liquefied, it would probably crystallize, and crystallize in the form of diamonds. For this reason, a preliminary communication which Prof. O. Lummer of Breslau made in 1913 on some experiments of his with the electric arc was at once exploited by the daily press, much to his annoyance. Further experiments of Lummer appear to prove, however, that the positive carbon of the electric arc would superficially fuse under certain conditions. The full account of these researches is hardly available in this country. As, however, Prof. G. Oesterheld of Basle was able to demonstrate Lummer's experiments at the annual meeting of the Swiss Chemical Society, held at Solothurn in February, this year, and to describe some experiments of his own concerning the same problem, we will notice these researches, though we remain skeptical.

It has long since been recognized that the temperature of the electric arc does not appear to vary when the current intensity and the arc length are varied between wide limits. The temperature of the arc being not directly determinable, the criterion on which this statement is based is that the brightness of the arc, which is practically the intensity of the radiation from the crater of the positive electrode, does not appear to vary, at atmospheric pressure at any rate, under the conditions mentioned. The constancy of the radiation intensity has been explained by the assumption that carbon is volatilized—apparently without fusing—in the arc, and that the arc temperature would correspond to the boiling point or the sublimation temperature of carbon. If that be so, the temperature should depend upon the pressure of the arc atmosphere, and should be lowered when the pressure is lowered, and raised when the pressure is increased, as in the case of other boiling points. Experimenting with homogeneous carbon electrodes, Lummer found that the arc temperature did not vary when the current intensity was varied between 10 and 68 amperes, and the arc length was changed between 1 millimeter and 18 millimeters, as long as the arc burned in an atmosphere at atmospheric pressure; but it did vary when the pressure was changed between 0.1 and 22 atmospheres, and, further—this is the most important point—when the current intensity was lowered below a certain minimum. The partial liquefaction of the positive electrode was observed at this very low current strength—not at any unusually high intensity. The phenomena are complex, of course.

In the first instance, Lummer had to make exact measurements of the total radiation from the arc, or rather the positive crater, and that involved the question whether carbon radiates as a black body or as a gray body.[1] Working with the Lummer-Brodhun spectro-photometer, Lummer found that the ordinary carbon filament of a glow-lamp radiated like a gray body, and that the relation between the brightness per unit area *H* and the absolute temperature *T* was $\frac{H_1}{H_2}=\left(\frac{T_1}{T_2}\right)^x$, where *x* was approximately constant only for small intervals. The *x* decreased, in fact, as the temperature was raised, rapidly at first, but seemed to assume a constant value of 8.5 when the temperature exceeded 2,700 deg. Cent. absolute, as the following figures will show:

Degrees Centigrade absolute =	1700,	1800,	1900,	2000,	2100,	2200,	2300,
x =	33,	28.5,	22.5,	19,	16.2,	14,	12,
Degrees Centigrade absolute =	2400,	2500,	2600,	2700,	2800	2900.	
x =	10,	9.2	8.8	8.5	8.5	8.5.	

Observations could not be carried above 2,900 deg. Cent., and extrapolations were not advisable. The radiation from the positive crater also proved to be of gray-body nature, and Lummer concluded, under certain assumptions, that the crater temperature is 4,200 deg. Cent. absolute at atmospheric pressure. When the pressure was reduced to 0.1 atmosphere, the temperature of the positive carbon went down to 3,940 deg. (always Centigrade absolute), and the intrinsic brightness was then reduced to 0.59 of the brightness at ordinary pressure. When the pressure was increased to 22 atmospheres, the brightness increased to eighteen times its value of atmospheric pressure; the corresponding temperature would be 6,000 deg., or, assuming black-body radiation, 7,500 deg., and probably exceed thus the estimate made for the temperature of the solar photosphere.

As regards the current intensity, Lummer found that it did not much affect the crater temperature at all the pressures. That, however, should not be interpreted to mean that the temperature corresponding to every pressure was a sublimation temperature. For the constancy held only as long as the current intensity was kept above a certain minimum, which varied with the pressure. When the current was reduced below that minimum, the temperature of the positive electrode rose locally, at any rate, when the pressure was kept within the range 0.2 and 2 atmospheres. That sounds paradoxical; the point is that the conditions of the electric discharge and the area of the incandescent portion change. As long as, at ordinary atmospheric pressure, the current intensity remained above the critical value, the current density (per unit area of incandescent electrode) remained fairly constant; but the area of the incandescent portion increased with increasing current intensity. When, however, the current intensity fell below that critical value—which is considerably smaller than the normal arc current—the area of the incandescent portion decreased noticeably, while the current density in this reduced portion rose, and the top of the electrode became fluid. The change of the temperature with pressure would then have to be ascribed to an alteration of the conditions of the electric discharge by the change of pressure; the nature of this alteration is not yet sufficiently understood.

When projected under a magnification of 30 diameters, the top of the positive electrode appeared liquid, and hexagonal specks (graphite?), about 0.1 millimeter in diameter, seemed to dart about in the liquid like little fishes. The liquid mass itself was only faintly luminous, and did not appear bright on Lummer's splendid photographs. The temperature of the liquid mass could not be measured; it was probably above 4,900 deg. Cent. absolute. The re-solidified liquid carbon was proved to be graphitic by chemical and other tests. Lummer thinks it possible that a fusion of carbon, which he observed within the pressure range of 0.2 and 2 atmospheres only, in atmospheres of air, nitrogen, oxygen, and carbon dioxide, may occur at higher pressures as well.

We mentioned already that Oesterheld was able to demonstrate this apparent fusion of carbon in the electric arc, which he placed in a vacuum at pressures from 0.06 to 1 atmosphere. Oesterheld himself stated that the triple point, solid-liquid-gaseous carbon, should be near 0.2, possibly below 0.1 atmosphere, according to the phase rule, and that carbon should have quite an appreciable vapor tension at its melting point. Accepting this, arc heating, which represents an extreme case of superficial heating, should be unsuitable for melting large bulks of carbon. He himself, therefore, went back to the often tried resistance heating in his own experiments, taking care not to ventilate his furnace, but to keep the carbon surrounded by a cushion of its own vapor. He also raised the intensity of the heating current very rapidly. We do not know particulars; Oesterheld did not actually melt a carbon rod, however, but showed afterward that the carbon looked as if it had been fused or partially fused. Similar claims were made by La Rosa in 1909, who observed also the bending of his hot carbon rod under its own weight, and were questioned on the strength of further experiments by V. P. Watts and C. E. Mendenhall in 1911.[2] Their temperature did not exceed 2,800 deg. Cent.; but they considered that the presence of impurities and of hydrocarbons in the carbon electrodes would account for the softening and other effects. La Rosa[3] tried to meet this objection by further researches and by accentuating, with Tammann, that the amorphous state is a phenomenon of undercooling and melting is a gradual diminution of viscosity; his specially purified carbon, he maintained, had fused, not at the surface, but in the interior, at the higher temperature and pressure prevailing there. But according to Lummer and to Oesterheld, high pressure is not only not desirable, but directly detrimental in experiments on the fusion of carbon. Lummer's experiments are certainly interesting. But incipient or partial fusion of carbon electrodes, in which hydrocarbons and mineral impurities may play an important part, cannot establish the fusibility of carbon. We want fusion of big lumps of something like pure carbon.—*Engineering.*

[1] In their recent investigations on "Estimation of High Temperature by the Method of Color Identity" (Physical Society Proceedings, April, 1915), C. C. Paterson and B. P. Dudding define a gray body as one which gives the same radiation curve as a black body at the same temperature, except that all the ordinates (intensity of radiation) are reduced in the same ratio.

[2] *Physical Review*, vol. xxxiii, page 65.

[3] See *Engineering*, vol. xciv, page 435.

The Electronic Theories of the Properties of Metals

In a course of lectures delivered at the Cavendish Laboratory during the Michaelmas term of 1886, Sir J. J. Thomson examined the dynamical result of assuming the passage of electricity through a metal to be of the same nature as through an electrolyte. The subject was dealt with more completely in "Applications of Dynamics to Physics and Chemistry" in 1888. The later discovery of the electron which might act as a carrier of electricity from molecule to molecule placed the idea on a much firmer footing, and in 1898 Riecke developed theories of the electrical and thermal conduction and thermo-electrical properties of metals, based on the existence between the molecules of carriers of positive and negative electricity. Two years later Drude worked out more systematically theories founded on the same basis, and it is his work which is usually quoted in accounts of electronic theories, generally with the simplification that only one type of carrier—the negative electron—is taken as moving freely between the molecules. These electrons are supposed to be produced by the dissociation of the electrically neutral metal atoms, what remains of the atom being left positively charged.

The moving electrons are assumed to have the same average kinetic energy as a molecule of a gas inclosed in a cavity in the metal would have. The nature of the impact of electron on metal atoms is not discussed, but as the motion of each metal atom is likely to be comparatively small, the gas laws which hold for the motions of the molecules of a light gas among those of a much heavier are applied and the electrons are said to have a mean free path of length λ. The motions are distributed in all directions equally, and the electrons cannot escape through the surface of the metal unless their speed perpendicular to the surface exceeds a certain limit. The action of ultra-violet light on the surface facilitates the emission.

When an electromotive force is applied to the metal there is superposed on this to and fro motion of the electrons a drift up the electric field, the relation of which to the field is such that the specific conductivity of the metal is proportional to $n\lambda/\sqrt{T}$ where n is the number of free electrons per cubic centimeter and T is the absolute temperature of the metal. Since the electrical conductivity of a pure metal is known to vary approximately inversely as the absolute temperature, this implies that $n\lambda$ must vary inversely as $\sqrt{T}$. As there is nothing on the one hand to suggest so considerable a change of the free space between the metal atoms with temperature, while on the other the facts of thermoelectricity are against any considerable decrease in the number of electrons per cubic centimeter as the temperature rises, it seems difficult to reconcile the law of variation of $n\lambda$ with experimental facts.

If a slope of temperature exists in a metal, the electrons coming from the hotter side of a cavity between two metal atoms will move more rapidly than when coming from the colder. There will therefore be a drift of energy toward the colder metal which bears to the slope of temperature such a relation that the heat conductivity of the metal is proportional to $n\lambda\sqrt{T}$. As the heat conductivity of a pure metal changes very little with change of temperature, this equation again implies that $n\lambda$ varies inversely as $\sqrt{T}$, and we have the same difficulty in understanding how this is brought about. On dividing the heat conductivity by T times the electrical conductivity the product $n\lambda$ disappears from the result, and we obtain a constant the value of which should be approximately 2.3×10^8 for all metals at all temperatures. At air temperatures the values found experimentally vary between 2 and 3×10^8, and at very low temperatures between 1.5 and 3×10^8. The agreement between the two results is undoubtedly good, but when the calculations are improved in accuracy by taking into account the variation of the speeds of the electrons about the mean value used by Drude, Lorentz finds the constant 1.5×10^8, which is not in such close agreement with experiment. For alloys and conducting salts the experimental values are considerably higher than for pure metals, and Koenigsberger and others have put this down to the part played by the atoms themselves in the conduction of heat. For quartz and other electrical insulators which are good conductors of heat there can be no question of the insignificance of the rôle of the free electrons.

Owing to the different values of the concentration n of electrons in different metals, there will be a flow of electrons through the surface of contact of two metals till the potential difference produced stops the flow. In an unequally heated metal the same process of compensation will occur. In the former case we get the Peltier and in the latter the Kelvin effect. The former agrees in order of magnitude with the values found by experiment, but as Sir J. J. Thomson has pointed out, it is difficult to reconcile the great decrease of electrical conductivity of a metal on melting with the small Peltier effect between solid and molten metal. The calculated Kelvin effect shows that the concentration n of the electrons must in all metals be nearly proportional to $\sqrt{T}$, a result which is not easily reconciled with that for $n\lambda$ deduced from the electrical or thermal conductivity.

Since a negative electron in motion in a magnetic field is acted on by a force transverse to its path, the theory affords a simple explanation of the Hall effect, and gives the right sign and order of magnitude for the effect in bismuth at ordinary temperatures, but the wrong sign for the effect at low temperatures, and for the effects at ordinary temperatures in iron and antimony.

In no field can the simple electron theory be said to have given a satisfactory quantitative account of the facts, and its elaboration in one region has in general led to greater difficulties in others. The kinetic energy of the electrons it postulates is so great that an increase of 1 deg. Cent. in their mean temperature involves a supply of heat ten times the specific heat of the metal. After pointing this out Sir J. J. Thomson, in 1907, in his "Corpuscular Theory of Matter," developed a new theory which may be called the doublet theory. According to this theory the atoms of a metal are grouped together in pairs, one of each pair positively, the other negatively charged. In ordinary circumstances the axes of these doublets point in all directions on the average equally. Under the action of an electric field the doublets tend to arrange themselves in lines, with the positive end of one near the negative of the next, and electrons may pass from the negative end of one doublet to the positive of the next, and so along the line of doublets.

On the assumption that the axis of the doublets distribute themselves according to the gas law, that their centers are spaced on the average b apart while the charges of the same doublet are d apart, and p electrons are discharged from a doublet per second, the electrical conductivity of the medium works out proportional to $nbdp/T$ where n is the number of doublets per cubic centimeter and T the absolute temperature. The experimental facts shows that $nbdp$ is independent of temperature. In the same way the transport of kinetic energy by an electron leaving a doublet at a higher, and joining one at a lower temperature, leads to a heat conductivity proportional to nb^2p, which the experimental facts show is independent of temperature. The quotient of the heat conductivity by T times the electrical conductivity on this theory comes $2.6b/d \times 10^8$, and as b/d must be greater than unity the agreement with the experimental value 2 to 3×10^8, is about as good as in the case of the simple theory. The presence of the b/d makes it possible to include in the theory those substances for which the quotient is high.

At the junction of two metals the excess flow from one metal will cause a difference of potential and an electric field which will change the orientation of the doublets until the flows are equalized. In an unequally heated metal the same method of compensation will come into play, and we have the Peltier and Kelvin effects.

If the rotation of a doublet in an electric field does not take place about the middle point, the two charges of the doublet move with different speeds. If they are in a magnetic field its action on them will tend to incline the axis of the doublet to the plane containing the two fields, and there will be a flow of electrons at right angles to both fields. The direction of the flow will be determined by that of the end of the doublet which moves most quickly. We thus have an explanation of the Hall effect, whether it be positive or negative.

No numerical comparisons of theory with experiment appear to have been made in the case of these thermo-electric and thermo-magnetic effects.

In his addresses to the Institute of Metals on May 5th, and to the Physical Society on June 25th, Sir J. J. Thomson dealt with the modification of his theory necessary to bring it into line with the discovery by Prof. Kamerlingh Onnes that at very low temperatures—4 degrees or 5 degrees absolute—the electrical conductivities of metals become infinite. The external electric field applied to the metal is assisted in bringing the axes of the doublets into line by the field produced by those doublets already in line. The kinetic energy of thermal motion of the doublets tends to destroy the alignment. At ordinary temperatures it is sufficient to destroy the alignment so soon as the external field is withdrawn, and the flow of electrons from doublet to doublet is stopped. But at very low temperatures the energy is not sufficient to modify an alignment once produced, and the flow of electrons continues when the external field is withdrawn. The conductivity in these circumstances will be very high.

From this short account of the present position of the two theories it will be seen that the doublet theory of Sir J. J. Thomson has shown a greater power than the electron theory of co-ordinating the facts of experiment. It has difficulties of its own, both in the nature of its fundamental assumptions and in its power of reproducing the facts quantitatively. It does not appear to provide electrons for emission by incandescent bodies, and in its latest development it involves serious changes not previously suspected in the thermal, thermomagnetic, and thermogalvanic properties of metals at the very low temperatures attained by Prof. Kamerlingh Onnes. But the great flexibility it has shown justifies a more generous treatment of it by those authors and lecturers who have been content to limit their exposition of these questions to the older electron theory.—*C. H. Lees in Nature.*

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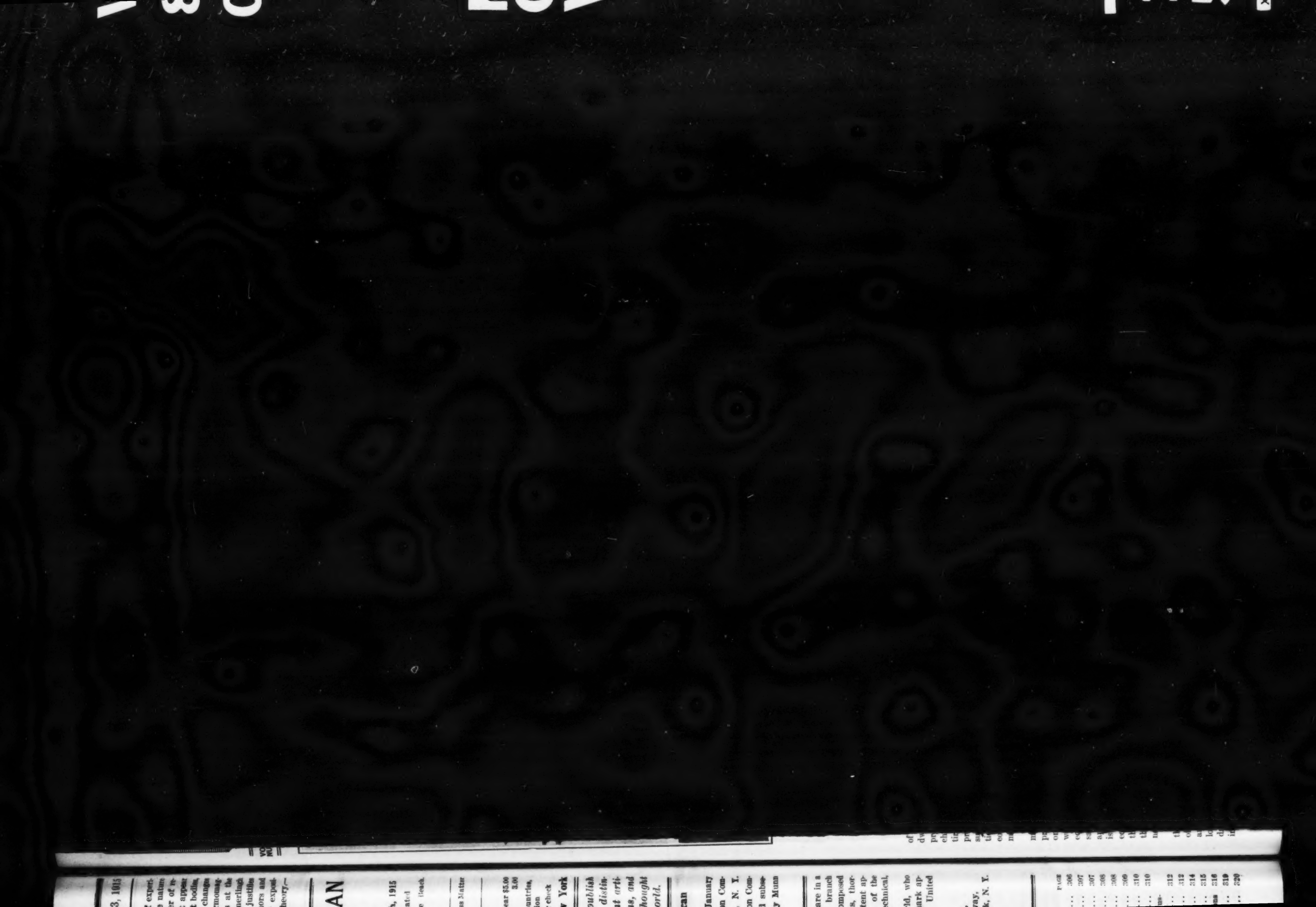
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